# NITROGEN FIXATION AND NEMATODE RESISTANCE OF 13 TROPICAL LEGUMES

BY

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This dissertation is
dedicated to my
parents,

Mr. Rami Reddi and
Mrs. Mahalaxmi

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TABLE OF CONTENTS

PAGE

## LIST OF TABLES

| TABLE | | PAGE |
|---|---|---|

| TABLE | | PAGE |
|---|---|---|
| 3-2 | Correlation coefficients of nodule dry weight (NDW) and plant dry weights (PDW) with N fixed $ha^{-1}$ $day^{-1}$ | 69 |
| 3-3 | Nitrogenase activity measurements of tropical legumes under fumigated (F) and nonfumigated (NF) conditions, 1980 and 1981 | 71 |
| 3-4 | Effect of fumigation on the nitrogenase activity of summer legumes | 78 |

## LIST OF FIGURES

Abstract of Dissertation Presented to the Graduate Council of the University of Florida in Partial Fulfillment of the Requirements for the Degree of Doctor of Philosophy

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Green manuring non-nematode-hosting legumes may provide both N and nematode control to the succeeding crops. To evaluate this, 13 tropical legumes and a marigold (_Tagetes erecta_ L.) cv 'Cracker Jack' were grown at different parts of the summer growing season under fumigation and non-fumigation during 1979, 1980, and 1981 at Gainesville, Florida. Average top growth N yields in kg $ha^{-1}$ at seeding stage were 40 for PI 305070 mungbean [_Vigna radiata_ (L.) Wilcz.]; 260 for pigeonpea [_Cajanus cajan_ (L.) Millsp.] line FL 45a; 190 for pigeonpea line FL 81d; 250 for pigeonpea cv 'Norman;' 170 for showy crotalaria (_Crotalaria spectabilis_ Roth.); 270 for slenderleaf crotalaria (_C. brevidens_ Benth.); 220 for hairy indigo (_Indigofera hirsuta_ L.); 170 for jointvetch (_Aeschynomene americana_ L.); 190 for velvetbean [_Mucuna deeringiana_ (Bort.) Merr.]; 10 for sesbania (_Sesbania macrocarpa_ Muhl.); 40 for lablab [_Lablab purpureus_ (L.) Sweet.]; 210 for soybean [_Glycine max_ (L.) Merr.]; 70 for alyceclover [_Alysicarpus vaginalis_ (L.) DC.] and 60 for marigold. The high N-yielding legumes produced 10,000 or over kg dry matter $ha^{-1}$ through their top growth. The grass crops planted behind these legumes

after their green manuring responded significantly for dry matter yield. The actual uptake of green-manured N by the grass crops was about 20 kg N $ha^{-1}$.

Parasitic nematode populations were monitored in the green manure crops and in the succeeding seasons' crops. Crops planted following incorporation of Norman pigeonpea, Fl 81d pigeonpea, showy crotalaria, slenderleaf crotalaria, hairy indigo, jointvetch, velvetbean and Crackerjack marigold had fewer numbers of root knot nematodes [*Meloidogyne incognita* (Kofoid and White) Chitwood]. Similarly, crops planted after jointvetch, hairy indigo, showy crotalaria and slenderleaf crotalaria had fewer numbers of sting nematodes (*Belonalaimus longicaudatus* Rau.) and those planted after hairy indigo and marigold had fewer numbers of lesion nematodes [*Pratylenchus brachyurus* (Godfrey) Goodey]. Early summer fumigation generally controlled only ectoparasites, sting nematodes and ring nematodes (*Criconemoides* spp.).

These studies indicate that the use of selected tropical legumes for annual green manuring in a multiple cropping system would lead to both biological control of parasitic nematodes and sizeable quantities of biologically-fixed N to the non-leguminous crops in the cropping system.

# INTRODUCTION

Florida's sandy soils are low in N and other nutrients, have low organic matter content and are congenial sites for plant parasitic nematodes. With the increasing fossil fuel energy prices, N fertilizers and fumigant prices are also increasing. These trends prompted interest in biological N fixation and pest control.

Legumes are known to increase soil fertility, particularly soil N, and consequently the productivity of succeeding cereal crops (Singh and Awasthi, 1978). Most of the popular legumes, like soybean, are highly susceptible to root knot nematodes (Hartwig, 1982). Therefore, there is a need to screen legumes for the rare combination of N fixation and parasitic nematode resistance. Legumes such as hairy indigo were reported as nonhosts to several plant parasitic nematodes (Overman, 1969). However, quantitative data of this kind, especially the N fixation and nematode resistance together, are meager.

In this study, 13 tropical legumes were evaluated for N fixation in the cropping systems under fumigated (1,2-dibromoethane) and nonfumigated conditions. The legumes were grown with low energy inputs with the objective of using them in low input production systems.

CHAPTER ONE
GREEN MANURING EFFECT OF FUMIGATED AND NONFUMIGATED TROPICAL LEGUMES ON THE SUCCEEDING CEREAL CROPS PRODUCTION

## Summary

Green manuring non-nematode host legumes may provide both N and nematode control to the succeeding crops. To evaluate this, 13 tropical legumes and a marigold (*Tagetes erecta* L.) cv 'Cracker Jack' were grown at different parts of the summer growing season under fumigation and nonfumigation during 1979, 1980, and 1981 at Gainesville, Florida. Average N yields in kg ha$^{-1}$ were 40 for PI 305070 mungbean [*Vigna radiata* (L.) Wilcz.]; 260 for pigeonpea [*Cajanus cajan* (L.) Millsp.] line 45a, 190 for pigeonpea line FL 81d, 250 for pigeonpea cv 'Norman;' 170 for showy crotalaria (*Crotalaria spectabilis* Roth.); 270 for slenderleaf crotalaria (*C. brevidens* Benth.); 220 for hairy indigo (*Indigofera hirsuta* L.); 170 for jointvetch (*Aeschynomene americana* L.); 190 for velvetbean [*Mucuna deeringiana* (Bort.) Merr.]; 10 for sesbania (*Sesbania macrocarpa* Muhl.); 40 for lablab [*Lablab purpureus* (L.) Sweet.]; 210 for soybean [*Glycine max* (L.) Merr.]; 70 for alyceclover [*Alysicarpus vaginalis* (L.) D.C.]; and 60 for marigold. The dry matter yields of legumes with the higher N yields usually exceeded 10,000 kg ha$^{-1}$ for full season production in all three years. Except for a few cases, fumigation did not influence the yields of green manure and subsequent crops.

The grass crops, rye (*Secale cereale* L.), ryegrass (*Lolium multiflorum* L.), corn (*Zea mays* L.), and wheat (*Triticum aestivum* L.),

produced significantly higher dry matter (up to 100%) by planting in summer legumes green manured plots than by planting in summer fallowed plots. The actual additional uptake of N by these grass crops was relatively low, up to 20 kg N $ha^{-1}$. However, the 20 kg N obtaned by cereal crops would be equivalent to 80 kg N applied through commercial fertilizers. The addition of high analysis N fertilizer, ammonium nitrate, up to 300 kg N $ha^{-1}$ to the green-manured plots did not increase the percent recovery of N from the green manure.

## Introduction

Florida sandy soils, in general, are poor in nutrient status, especially available N, have low organic matter content, and are suitable sites for plant parasitic nematodes. Recent fertilizer price increases have caused a decline in economically optimum application rates for N and other nutrients, which may eventually result in lower crop production per unit area. Legumes are known to increase soil N, and consequently the productivity of succeeding cereal crops (Singh and Awasthi, 1978). Similar results with blue lupine (*Lupinus angustifolius* L.) followed by sorghum were shown by Gallaher.[1]

Nematodes, particularly root knot (Meloidogyne sp.) and sting (*Belonolaimus longicaudatus* Rau.), are major crop pests in Florida. Chemical control of these nematodes gives only temporary control and

[1] Gallaher, R. N. 1980. Value of residues, mulches or sods in cropping systems. Univ. of Fla., IFAS, Fla. Coop. Ext. Multicropping Minimum Tillage (MMT)-5, 5 p.

often results in subsequent higher nematode populations than untreated. Higher costs and application difficulties are further drawbacks to chemical control.

Ideally, crops that need low N input and are resistant to plant parasitic nematodes are desirable. Unfortunately, there are no grain crops that can satisfy both these requirements. A second choice is to have crops in the cropping systems that supply N and reduce plant parasitic nematodes, at least partially, for companion and/or succeeding crops.

Quantitative data of this kind are meager; so the present study was initiated. A number of tropical legumes and a marigold variety were evaluated for their biomass production, N yield, nematode resistance and green-manuring effects on succeeding cereal crop production. These studies were carried out under low technology situations with the objective of limiting fossil fuel energy use in agriculture.

## Materials and Methods

This 3-year study (1979-81) was conducted at the main agronomy farm, University of Florida, Gainesville, Florida. The soil was an Arredondo fine sand (loamy, siliceous, hyperthermic, Grossarenic Paleudult). The study was carried out on two proximately-located fields: E6 in 1979 and 1981 and S16 in 1980. The 1979 summer experiment was reported earlier (Soffes, 1981[2]). These data are presented here to show the comprehensive picture on tropical legumes.

[2]Soffes, A. R. 1981. Legume cover crops selected for high nitrogen yields and their effects on plant-parasitic nematodes. M.S. Thesis, Agronomy Dept., Univ. of Fla., Gainesville, Fla.

The summer legumes and marigold were grown for two or three different periods: Apr. 15th to Aug. 15th (early season production), Apr. 15th to Sept. 15th (full season production), and June 7th to Sept. 15th (late season production). These three periods are designated as early summer season, full summer season and late summer season, respectively. Full summer season plantings of 3 years and early summer planting of 1981 were arranged in a split-plot design with fumigation (F) and nonfumigation (NF) as main-plot treatments and crops (Table 1-1) and fallow as sub-plot treatments. The other early and late summer season plantings only had the crops and fallow treatments arranged in a randomized complete block design. Five replications were included in all the plantings.

At the end of each summer season (September), these legumes were incorporated into soil of plots on which they were grown by a series of tractor and manual operations. In the succeeding season, several test crops were planted in the original legume plots. The test crops used after each full summer season experiment and their time of planting and harvesting with details of plot arrangement are shown in Fig. 1-1. These test crops included snap beans (*Phaseolus vulgaris* L.) cv 'Blue lake bush', corn (*Zea mays* L.) cv 'Funk G4507', wheat (*Triticum aestivum* L.) cv 'FL 301', ryegrass (*Lolium multiflorum* L.) cv 'Florida 80', rye (*Secale cereale* L.) cv 'Florida Black' and soybean [*Glycine max* (L.) Merr.] cv 'Williams'.

After green manuring in 1979, rye in fall season and corn in spring season were planted in both the fumigated and nonfumigated, green-

Table 1.1. List of crops (sub-plot treatments) in the main summer experiments of 1979, 1980, and 1981.

| Common name | Scientific name | Summer seasons planted |
|---|---|---|
| PI 305070 mungbean | _Vigna radiata_ (L.) Wilcz. | 1979, 1980 and 1981 |
| Pigeonpea cv 'Norman' | _Cajanus cajan_ (L.) Millsp. | 1979, 1980 and 1981 |
| Pigeonpea line 'FL 45a' | _Cajanus cajan_ (L.) Millsp. | 1979 |
| Pigeonpea line 'FL 81d' | _Cajanus cajan_ (L.) Millsp. | 1980 and 1981 |
| Showy crotalaria | _Crotalaria spectabilis_ Roth. | 1979, 1980 and 1981 |
| Slenderleaf crotalaria | _Crotalaria brevidens_ Benth. | 1981 |
| Hairy indigo | _Indigofera hirsuta_ L. | 1979, 1980 and 1981 |
| Jointvetch | _Aeschynomene americana_ L. | 1980 and 1981 |
| Velvetbean | _Mucuna deeringiana_ (Bort.) Merr. | 1979, 1980 and 1981 |
| Alyceclover | _Alysicarpus vaginalis_ (L.) DC. | 1981 |
| Lablab | _Lablab purpureus_ (L.) Sweet. | 1979 |
| Sesbania | _Sesbania macrocarpa_ Muhl. | 1979 |
| Soybean cv 'Jupiter' | _Glycine max_ (L.) Merr. | 1981 |
| Marigold cv 'Cracker Jack' | _Tagetes erecta_ L. | 1980 and 1981 |
| Fallow (bare soil) | - | 1979, 1980 and 1981 |

manured plots of full summer season (Fig. 1-1). After green manuring in 1980, ryegrass was planted in the nonfumigated, early summer season plots and late summer season plots in the winter season. In the same season, in the full summer season plots, which comprised fumigated and nonfumigated treatments, wheat was planted (Fig. 1-1).

Green manure contributions to the cereals by the summer legumes were estimated by deducting the cereal N uptake in the fallow plots from the cereal N uptake in the summer legume green-manured plots. The assumption made here was that the uptake of N by the cereal crop in the fallow plots was approximately equivalent to the soil N contributions in the green-manured plots. From these estimated contributions, the percent recovery of N from the green manure was calculated.

To fumigate the soil, 1,2-dibromoethane (SOILBROM-90®EDB) was applied at the rate of 65 kg $ha^{-1}$ by injecting 15 cm below ground through chisels located 30 cm apart. Each year the fumigant was applied once in the last week of March, 3 weeks before planting the summer legumes.

Green manure crops grown in 1979 received 12 kg N $ha^{-1}$ through 4-8-16 (N-$P_2O_5$-$K_2O$) fertilizer. With the exception of 60 kg N $ha^{-1}$ applied to nonlegume marigold in 1980, the legumes did not receive any N fertilizer in 1980 and 1981. The succeeding grass crops also did not receive any N fertilizer, with the exception of 100 kg N $ha^{-1}$ applied as ammonium nitrate to the corn planted in the lablab green-manured plots in 1979. Recommended P and K fertilizers and water were applied to all the treatments. The fields were kept weed-free by hand hoeing and glyphosate (ROUNDUP®) was applied frequently to keep the fallow treatment weed-free.

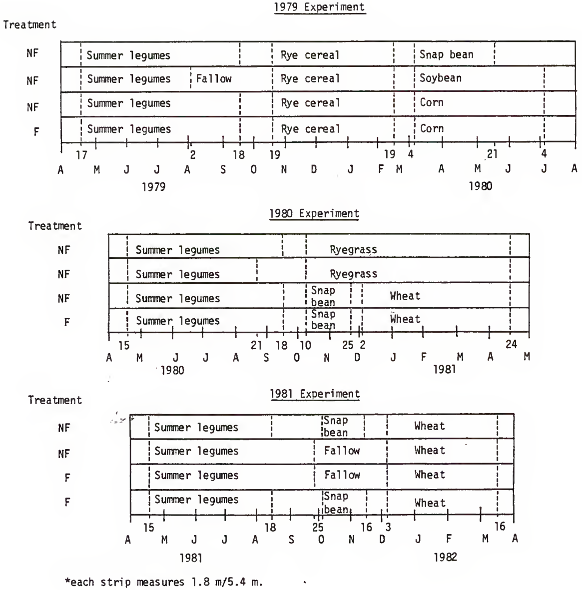


Fig. 1-1. Planting and harvesting dates and pattern of cropping sequences of 1979, 1980, and 1981 experiments.

Total dry matter yields of top growth of crops were measured from a net plot area of 3.24 $m^2$. In 1981, the leaf drop from the fumigated and nonfumigated plots of FL 81d pigeonpea, Norman pigeonpea and showy crotalaria was collected and the amount of N added through that process was calculated. Total N in the plant tissue was determined according to Gallaher et al. (1976).

In 1981, N fertilizer treatments (0, 50, and 100 kg N $ha^{-1}$) from ammonium nitrate were super-imposed over the green-manured plots and fumigated and nonfumigated treatments were combined together. Plant samples were harvested by cutting across the original fumigated and nonfumigated plots and the net area of harvest was 4.6 $m^2$.

Organic matter was determined on soil samples taken prior to planting and 2 months after legumes were incorporated into soil in 1981 by Walkley and Black method (Walkley and Black, 1934). Data were subjected to analysis of variance and mean separation by Duncan's Multiple Range Test.

## Results and Discussion

The dry matter yield, percent N of composite samples and derived N yield of top growth of summer legumes grown in natural conditions (NF) were averaged over 3 years and are presented by growth period in Table 1-2. The data presented in Table 1-2 indicate that velvetbean is the only crop that produced significantly higher N yield in early summer planting compared to the yield in full and late summer season plantings. This was possible through higher dry matter yield than in the other two plantings. In the later growth periods (included September growth),

Table 1-2. Dry matter yield and nitrogen concentration and yield of tropical legumes and marigold grown at different growth periods under nonfumigated (NF) conditions (average of 1979, 1980, and 1981).

| Crops | Production periods in summer† | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Early | Full | Late | Early | Full | Late | Early | Full | Late |
| | Dry matter yield | | | Nitrogen concentration | | | Nitrogen yield | | |
| | t ha$^{-1}$ | | | % | | | kg ha$^{-1}$ | | |
| PI 305070 mungbean | 2.1 AB‡f§ | 1.0 B e | 2.8 A e | 1.5 A fg | 1.0 B fg | 1.4 A cd | 30 A d | 10 A d | 40 A f |
| FL 45a pigeonpea | 3.9 B e | 9.1 A bc | -- | 3.0 A a | 2.8 A a | -- | 120 B c | 260 A a | -- |
| FL 81d pigeonpea | 9.7 A ab | 10.8 A b | 9.5 A a | 2.0 A cde | 1.8 A d | 2.0 A ab | 190 A a | 190 A bc | 190 A a |
| Norman pigeonpea | 9.5 B b | 13.3 A a | 8.8 B a | 2.1 A cd | 1.9 A cd | 2.1 A ab | 190 B a | 250 A a | 180 B a |
| Showy crotalaria | 9.1 A b | 10.2 A bc | 5.7 B cd | 1.8 A def | 1.6 A de | 1.7 A bc | 160 A abc | 170 A c | 90 B de |
| Slenderleaf crotalaria | 11.4 B a | 14.4 A a | 8.4 C ab | 1.6 A ef | 1.9 A cd | 1.8 A bc | 190 B a | 270 A a | 150 B bca |
| Hairy indigo | 9.0 B bc | 13.0 A a | 6.2 Ccd | 2.0 A de | 1.8 A d | 1.8 A b | 170 B ab | 220 A ab | 110 C bcd |
| Jointvetch | 7.8 B bcd | 10.0 A bc | 6.9 B bc | 2.2 A cd | 1.8 B d | 2.3 A a | 170 A ab | 170 A bc | 150 A ab |
| Velvetbean | 7.1 A cd | 5.9 A d | 4.4 B e | 2.6 A ab | 2.4 A b | 2.4 A a | 190 A a | 140 B c | 100 C cd |
| Sesbania | 0.5 A f | 0.5 A e | -- | 2.4 A bc | 0.7 B g | -- | 10 A d | 5 A d | -- |
| Lablab | 1.9 A f | 1.0 A e | -- | 2.2 A cd | 2.3 A b | -- | 40 A d | 20 A d | -- |
| Jupiter soybeans | 6.8 B d | 8.4 A c | 9.8 A a | 1.9 A de | 2.3 A bc | 2.2 A a | 130 B bc | 190 A bc | 210 A a |
| Alyceclover | -- | 1.2 B e | 5.6 A cd | -- | 1.3 A ef | 1.3 A d | -- | 20 A d | 70 A def |
| Crackerjack marigold | 4.7 A e | 5.1 A d | 3.7 A e | 1.2 A g | 0.7 B g | 1.3 A d | 60 A d | 40 A d | 50 A ef |

†Production periods = Early (April 15th-Aug. 15th), Full (April 15th-Sept. 15th), Late (June 7th-Sept. 15th).
‡Means in the same row not marked with the same upper case letter are significantly different at 5% level according to Duncan's Multiple Range Test.
§Means in the same column not marked with the same lower case letter are significantly different at 5% level according to Duncan's Multiple Range Test.

velvetbean caterpillar (Anticarsia gemmatalis Hiibner) severely damaged the foliage and reduced the dry matter yield. Therefore, early summer season was the best choice to grow velvetbean.

Mungbean, FL 81d pigeonpea, jointvetch and Cracker Jack marigold produced the same N yields in all three growth periods. Therefore, they can be grown in any of the three different growth periods. In this case, where total N yields did not change with the growth period, the growth period that gives the highest N percentage in the plant tissue should be preferred over the other because the potentially mineralizable or immobilizable N is a function of the C/N ratio of the incorporated organic matter (Reddy et al., 1979).

Norman pigeonpea, slenderleaf crotalaria and hairy indigo produced significantly higher N yield in full summer season growth period compared to the growth in early and late summer seasons through higher dry matter production. The higher dry matter production of full summer season crops was a result of longer growing period compared to the other two periods. Showy crotalaria produced significantly lower N yield in the late summer season compared to early and full summer season crops and, therefore, 15th Apr. planting was desirable. In contrast, Jupiter soybean produced the lowest yield in the early summer season compared to full and late summer seasons, therefore, a later planting date (June 7th planting) is preferable for this crop.

In addition to the top growth N, the senesced leaves added substantial amounts of N to the soil. The estimations for the three crops studied are given in Table 1-3.

Table 1-3. Dry matter and nitrogen yields of leaves dropped from the green manure crops grown during middle April to middle September, under fumigated (F) and nonfumigated (NF) conditions, 1981.

| Crop | Dry matter | | Nitrogen | | Nitrogen yield | |
|---|---|---|---|---|---|---|
| | NF | F | NF | F | NF | F |
| | —kg $ha^{-1}$— | | —%— | | —kg $ha^{-1}$— | |
| FL 81d pigeonpea | 2790 | 2990 | 2.1 | 2.3 | 42 | 57 |
| Norman pigeonpea | 2740 | 2850 | 1.8 | 1.7 | 44 | 48 |
| Showy crotalaria | 2990 | 2980 | 2.0 | 2.2 | 61 | 65 |

Fumigation Effects

Fumigation and nonfumigation treatment comparisons for dry matter and N yields for the full season growth period 1979 (Table 1-4), 1980 (Table 1-5), and 1981 (Table 1-7) and early growth period in 1981 (Table 1-6) are presented.

In 1979, there was no fumigation effect on the N yield of the crops. Norman pigeonpea and hairy indigo produced significantly higher N yields than the other legumes (Table 1-4).

In 1980, fumigation did not influence any of the crops' dry matter and N yields with the exception of mungbean. Mungbean was heavily infected with root knot nematodes under nonfumigated conditions in the early stages of growth and resulted in poor establishment and yields. Among the crops, Norman and FL 81d pigeonpeas and hairy indigo out-performed all the other crops for dry matter and N yields (Table 1-5).

In 1981, fumigation had no influence on the crop yields grown in early and full summer seasons (Tables 1-6 and 1-7). Among the crops, in early summer season, Norman and FL 81d pigeonpeas and velvetbean produced significantly higher N compared to the other crops (Table 1-6). In the full summer season, Norman pigeonpea out performed all the other crops in N production (Table 1-7).

These data, representing 3 years' trials and four different tests, consistently indicated that the tropical legumes Norman and FL 81d pigeonpeas, showy and slenderleaf crotalarias, hairy indigo, velvetbean and jointvetch did not respond to fumigation. This implies that these crops are nonhosts to plant parasitic nematodes. The lower yields

Table 1-4. Comparison of full summer season crop dry matter and nitrogen yields for fumigated (F) and nonfumigated (NF) green manure crops in 1979.

| Crop | Dry matter yield | | Nitrogen yield | | |
|---|---|---|---|---|---|
| | NF | F | NF | F | Means |
| | kg ha$^{-1}$ | | | | |
| Mungbean | 590 c†* | 3090 ef | 5 | 48 | 27 d |
| FL 45a pigeonpea | 9110 a | 7950 c | 255 | 198 | 227 ab |
| Norman pigeonpea | 11480 a | 11610 ab | 246 | 290 | 268 a |
| Showy crotalaria | 9720 a | 11170 b | 160 | 205 | 182 bc |
| Hairy indigo | 10730 a * | 14060 a | 240 | 296 | 268 a |
| Velvetbean | 5840 b | 4540 de | 145 | 112 | 128 c |
| Lablab | 1050 c | 1540 f | 24 | 36 | 30 d |
| Sesbania | 490 c * | 5930 cd | 3 | 68 | 35 d |

*Means in the same row marked with an asterisk are significantly different at 5% level according to Duncan's Multiple Range Test.

†Means in the same column not marked with the same lower case letter are significantly different at 5% level according to Duncan's Multiple Range Test.

Table 1-5. Comparison of full summer season crop dry matter and nitrogen yields for fumigated (F) and nonfumigated (NF) green manure crops in 1980.

| Crop | Dry matter | | Nitrogen yield | |
|---|---|---|---|---|
| | NF | F | NF | F |
| | kg ha$^{-1}$ | | | |
| Mungbean | 1650* d† | 3440 d | 21* d | 54 c |
| FL 81d pigeonpea | 9840 b | 10200 a | 175 ab | 195 a |
| Norman pigeonpea | 11170 a | 11360 a | 191 a | 178 a |
| Showy crotalaria | 8650 b | 8460 b | 150 b | 137 b |
| Hairy indigo | 12000 a | 11670 a | 185 a | 164 b |
| Jointvetch | 8720 b | 8970 b | 156 b | 152 b |
| Velvetbean | 5160 c | 5900 c | 104 c | 126 b |

*Means in the same row marked with an asterisk are significantly different at 5% level according to Duncan's Multiple Range Test.

†Means in the same column not marked with the same lower case letter are significantly different at 5% level according to Duncan's Multiple Range Test.

Table 1-6. Comparison of early summer season crop dry matter and nitrogen yields for fumigated (F) and nonfumigated (NF) green manure crops in 1981.

| Crop | Dry matter yield | | | Nitrogen yield | | |
|---|---|---|---|---|---|---|
| | NF | F | Mean | NF | F | Mean |
| | kg $ha^{-1}$ | | | | | |
| Mungbean | 2135 | 3000 | 2560 e‡ | 26 | 33 | 29 d |
| FL 81d pigeonpea | 11310 | 10920 | 11110 b | 202 | 188 | 195 ab |
| Norman pigeonpea | 13040 | 15700 | 14370 a | 202 | 233 | 218 a |
| Showy crotalaria | 11250 | 11440 | 11350 b | 129 | 142 | 136 c |
| Slenderleaf crotalaria | 11370 | 12000 | 11720 b | 186 | 170 | 178 b |
| Hairy indigo | 11830 | 10380 | 11110 b | 175 | 183 | 179 b |
| Jointvetch | 8910 | 8380 | 8640 c | 182 | 157 | 169 b |
| Velvetbean | 8420 | 8070 | 8240 c | 216 | 189 | 202 ab |
| Jupiter soybean | 6800 | 5800 | 6300 d | 130 | 125 | 128 c |
| Marigold | 3900 | 3670 | 3830 e | 29 | 30 | 30 d |
| Mean | 8850 A† | 8930 A | 8890 | 147 | 144 A | 144 A |

†Means in the same row not marked with the same upper case letter are significantly different at 5% level according to Duncan's Multiple Range Test.

‡Means in the same column not marked with the same lower case letter are significantly different at 5% level according to Duncan's Multiple Range Test.

Table 1-7. Comparison of full summer season crop dry matter and nitrogen yields for fumigated (F) and nonfumigated (NF) green manure crops in 1981.

| Crop | Dry matter yield | | | Nitrogen yield | | |
|---|---|---|---|---|---|---|
| | NF | F | Mean | NF | F | Mean |
| | kg $ha^{-1}$ | | | | | |
| Mungbean | 650 | 1350 | 1000 g‡ | 6 | 10 | 8 e |
| FL 81d pigeonpea | 11670 | 14120 | 12900 c | 203 | 269 | 236 bc |
| Norman pigeonpea | 17350 | 18140 | 17750 a | 309 | 388 | 348 a |
| Showy crotalaria | 12330 | 15000 | 13670 bc | 184 | 177 | 181 cd |
| Slenderleaf crotalaria | 14420 | 15000 | 14690 b | 271 | 254 | 262 b |
| Hairy indigo | 16120 | 19510 | 17810 a | 247 | 287 | 267 b |
| Jointvetch | 11230 | 10790 | 11010 d | 192 | 192 | 192 cd |
| Velvetbean | 6650 | 6230 | 6440 f | 177 | 149 | 163 d |
| Jupiter soybean | 8360 | 8920 | 8640 e | 190 | 208 | 199 cd |
| Alyceclover | 1220 | 1280 | 1250 g | 16 | 15 | 15 e |
| Marigold | 5100 | 5130 | 5110 f | 35 | 33 | 34 e |
| Mean | 9550 B† | 10490 A | | 166 A | 180 A | |

†Means in the same row not marked with the same upper case letter are significantly different at 5% level according to Duncan's Multiple Range Test.
‡Means in the same column not marked with the same lower case letter are significantly different at 5% level according to Duncan's Multiple Range Test.

observed for alyceclover, mungbean, lablab and sesbania under both fumigated and nonfumigated conditions resulted partially from the extreme susceptibility of these crops to root knot nematodes (Reddi et al., 1982).

Uptake of Green-Manured Nitrogen

The tropical legumes and marigold were incorporated as green manure at the end of each summer season. Various grass crops were planted in these green-manured plots, in the succeeding fall, winter and spring seasons. The uptake of N by the grasses from the green-manured plots was compared with N uptake from the fallow plots.

The dry matter yields for all four grass crops in five different tests are shown in Table 1-8. The results indicate that grass crops benefited from planting in the green-manured plots with tropical legumes compared to planting in plots that were summer fallowed or marigold green-manured (Table 1-8). Ahlawat et al. (1981) reported that winter legumes such as chickpea (Cicer arietinum L.), lentil (Lens esculenta Moench.), and pea (Pisum sativum L.) reduced the need for fertilizer N in corn to the extent of 18-68 kg $ha^{-1}$ compared with corn planted after cereal wheat or fallow. Similarly, Singh (1971) reported that incorporation of 35 t $ha^{-1}$ of wild legumes such as Tephrosia purpurea and jointvetch increased the yield and quality of rice (Oryza sativa L.) and the yield of a subsequent wheat crop.

Fumigation at planting of the green manure crop did not make any significant difference in the dry matter production of the succeeding rye crop in 1979 and wheat crop in 1980. A positive effect of summer

Table 1-8. Dry matter yields of grass crops planted in the green-manured and fallow plots, 1979 and 1980.

| Green-manured crop | Test crops dry matter yield | | | | | |
|---|---|---|---|---|---|---|
| | Rye (1979) | Corn (1979) | | Ryegrass (1980) | | Wheat (1980) |
| | Full† | Full | | Early | Late | Full |
| | Mean | NF‡ | F | NF | NF | Mean |
| | kg ha$^{-1}$ | | | | | |
| PI 305070 mungbean | 4330 bc§ | 3290 b | 3510 d | 1440 bcd | 890 c | 2370 c |
| FL 45a pigeonpea | 4880 ab | 3590 b | 3470 d | -- | -- | -- |
| FL 81d pigeonpea | -- | -- | -- | 1730 abc | 1340 a | 3020 ab |
| Norman pigeonpea | 4510 bc | 3500 b * | 4070 c | 1670 abcd | 1270 ab | 2560 bc |
| Showy crotalaria | 4790 ab | 4520 a * | 6760 a | 2065 a | 1140 abc | 3520 a |
| Hairy indigo | 5200 a | 4430 a | 4830 b | 1900 ab | 1170 abc | 2930 bc |
| Jointvetch | -- | -- | -- | 1180 cd | 1370 a | 2650 bc |
| Velvetbean | 4290 bc | 3030 bc* | 4170 c | 1230 cd | 1310 a | 3120 ab |
| Sesbania | 4340 bc | 2540 c * | 3510 d | -- | -- | -- |
| Lablab | 4090 c | 4210 a | 4410 bc | -- | -- | -- |
| Marigold | -- | -- | -- | 1130 d | 920 c | -- |
| Fallow | 3390 d | 2650 c | 2780 e | 1280 cd | -- | 1670 d |

†Production periods = Early (Apr. 15th-Aug. 15th), Full (Apr. 15th-Sept. 15th), Late (June 7th-Sept. 15th).
‡NF = Nonfumigated, F = fumigated.
*Means in the same row marked with an asterisk are significantly different at 5% level according to Duncan's Multiple Range Test.
§Means in the same column not marked with the same lower case letter are significantly different at 5% level according to Duncan's Multiple Range Test.

fumigation was seen in spring corn yields planted in the Norman pigeonpea, showy crotalaria, velvetbean and sesbania green-manured plots. These differences were probably from the larger amounts of green manure N added to the soil by these legumes under the fumigated conditions (Table 1-4).

Percent recovery of green-manured N is quite low for all crops (Table 1-9). However, these estimates are in agreement with the theoretically possible N availability for incorporated residues with about 2% N (Reddy et al., 1977).

## Nitrogen Fertilization and Organic Nitrogen Availability

In 1981, wheat was grown on green-manured plots fertilized with 0, 50 and 100 kg N $ha^{-1}$. The dry matter and N yields obtained from these plots (top growth of wheat only) are presented in Table 1-10. The data in Table 1-10 indicate that the wheat responded significantly to the inorganic fertilizer. Green-manured N had an influence on the wheat only when it was grown without any additional fertilization (Table 1-10). Theoretically, the high analysis ammonium nitrate should release some of the immobilized green-manured N and increase the availability of total N. However, this effect could not be seen in this case, probably because the field conditions were not as controllable as laboratory conditions where the theoretical estimates were generated. Therefore, it is not advisable to apply fertilizer N to increase the availability of N from the incorporated legume residue under field conditions. Further, the recovery of fertilizer N by the wheat in fallow plots was about 25%. Therefore, the 10 kg N $ha^{-1}$

Table 1-9. Nitrogen uptake of cereals and the calculated percent recovery of green-manured nitrogen, 1979 and 1980.

| Green-manured crop | Nitrogen uptake | | | | | Recovery of nitrogen§ | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1979 | | 1980 | | | 1979 | | 1980 | | |
| | Rye Full† Mean | Corn Full Mean | Ryegrass Early NF‡ | Ryegrass Late NF | Wheat Full Mean | Rye Full Mean | Corn Full Mean | Ryegrass Early NF | Ryegrass Late NF | Wheat Full Mean |
| | kg ha$^{-1}$ | | | | | % | | | | |
| Mungbean | 42 bc¶ | 24 de | 11 ab | 9 d | 16 bc | 34.0 | 15.0 | 0 | 0 | 10.5 |
| FL 45a pigeonpea | 47 ab | 25 de | -- | -- | -- | 6.2 | 2.2 | -- | -- | -- |
| FL 81d pigeonpea | -- | -- | 15 ab | 15 ab | 20 b | -- | -- | 2.2 | 1.8 | 4.3 |
| Norman pigeonpea | 43 abc | 29 cd | 17 a | 14 abc | 18 b | 3.7 | 3.3 | 3.2 | 1.9 | 3.4 |
| Showy crotalaria | 45 abc | 43 b | 17 a | 11 bcd | 26 a | 6.3 | 12.6 | 4.2 | 0 | 10.2 |
| Hairy indigo | 50 a | 32 c | 17 a | 12 abcd | 20 b | 6.3 | 4.5 | 3.6 | 0.8 | 5.5 |
| Jointvetch | -- | -- | 12 ab | 15 ab | 19 b | -- | -- | 3.2 | 3.3 | 4.6 |
| Velvetbean | 41 bc | 25 de | 10 b | 16 a | 21 b | 6.2 | 3.9 | 0 | 4.7 | 7.1 |
| Sesbania | 42 bc | 22 ef | -- | -- | -- | 25.0 | 5.7 | -- | -- | -- |
| Lablab | 39 c | 48 a | -- | -- | -- | 10.0 | 33.0 | -- | -- | -- |
| Marigold | -- | -- | 11 ab | 11 bcd | -- | -- | -- | 0 | 0 | -- |
| Fallow | 33 d | 20 f | 11 ab | 11 bcd | 12 c | 0 | 0 | 0 | 0 | 0 |

†Production periods = Early (Apr. 15th-Aug. 15th), Full (Apr. 15th-Sept. 15th), Late (June 7th-Sept. 15th).
‡NF = nonfumigated, F = fumigated.
§Recovery of nitrogen = $\frac{\text{nitrogen uptake grass from legume plot - nitrogen uptake grass from fallow plot}}{\text{nitrogen in green-manured legume}}$
¶Means in the same column not marked with the same lower case letter are significantly different at 5% level according to Duncan's Multiple Range Test.

Table 1-10. Effect of fertilizer nitrogen levels on the dry matter and nitrogen uptake of wheat planted in the green-manured plots, 1981.

| Green-manured crop | Dry matter yield | | | Nitrogen uptake | | |
|---|---|---|---|---|---|---|
| | Control | 50 kg N $ha^{-1}$ | 100 kg N $ha^{-1}$ | Control | 50 kg N $ha^{-1}$ | 100 kg N $ha^{-1}$ |
| | kg $ha^{-1}$ | | | | | |
| Mungbean | 560 | 1260 | 1770 | 9 | 19 | 25 |
| FL 81d pigeonpea | 640 | 1290 | 1730 | 9 | 20 | 23 |
| Norman pigeonpea | 580 | 1130 | 1460 | 9 | 17 | 24 |
| Showy crotalaria | 660 | 1340 | 2100 | 11 | 23 | 33 |
| Slenderleaf crotalaria | 500 | 1190 | 1830 | 8 | 18 | 31 |
| Hairy indigo | 520 | 870 | 1520 | 9 | 13 | 24 |
| Jointvetch | 560 | 1160 | 1690 | 8 | 16 | 25 |
| Velvetbean | 630 | 1180 | 1680 | 9 | 18 | 26 |
| Soybean | 590 | 1170 | 1610 | 8 | 16 | 22 |
| Alyceclover | 540 | 1110 | 1880 | 8 | 16 | 31 |
| Marigold | 470 | 1060 | 1630 | 7 | 16 | 23 |
| Fallow | 400 | 1290 | 1880 | 6 | 19 | 24 |
| Mean | 550 C† | 1170 B | 1730 A | 8 | 17 | 26 |

†Means in the same row not marked with the same upper case letter are significantly different at the 5% level according to Duncan's Multiple Range Test.

obtained by the cereals in these soils on the green-manured plots implies that about 40 kg N $ha^{-1}$ of inorganic N was actually applied. Giri and De (1979) reported that the N benefits from a previous crop of peanut (Arachis hypogaea L.) and cowpea [Vigna unguiculata (L.) Walp.] were equivalent to an application of about 60 kg N $ha^{-1}$ for a pearl millet [Pennisetum americanum (L.) Leeke] crop following a previous crop of pearl millet.

### Green Manuring Effects on the Soil Organic Matter Content

The experimental sites were very low in soil organic matter content with the average being 0.9%. The differences in the soil organic matter percentage prior to planting and after 2 months of green manuring were not significant (Table 1-11). At the second sampling date, the incorporated organic material was still in the woody form and only the leaves and tiny stems were decomposed. However, there was a positive trend in the organic matter concentration of green-manured plots (Table 1-11).

## Conclusions

The 3 years of growth period tests showed that all the tropical legumes yielded higher N in full summer season (Apr. 15th-Sept. 15th) than in other growth periods, with the exception of velvetbean which yielded higher in early summer season (Apr. 15th-Aug. 15th). The tropical legumes hairy indigo, jointvetch, showy crotalaria, slender-leaf crotalaria, velvetbean and FL 81d and Norman pigeonpeas were resistant or nonhosts to plant parasitic nematodes and showed no

Table 1-11. Percent soil organic matter (OM) prior to green manure crop planting and 2 months after green manuring, 1981.

| Green manure crop | OM prior to planting | 2 months after green manuring |
|---|---|---|
| Mungbean | 0.86 | 1.01 |
| FL 81d pigeonpea | 0.94 | 1.02 |
| Norman pigeonpea | 0.92 | 1.00 |
| Showy crotalaria | 0.97 | 1.05 |
| Slenderleaf crotalaria | 0.90 | 1.04 |
| Hairy indigo | 0.81 | 1.03 |
| Jointvetch | 0.84 | 0.93 |
| Velvetbean | 0.97 | 1.03 |
| Soybean | 0.94 | 1.00 |
| Alyceclover | 0.88 | 1.01 |
| Marigold | 0.95 | 0.98 |
| Fallow | 0.97 | 0.98 |

significant differences for N yield between fumigated and nonfumigated treatments. Other tropical legumes were susceptible to parasitic nematodes even under fumigated conditions. The grass crops grown in the green-manured plots in the winter and spring seasons without any inorganic N responded to the green manuring positively but the yields were below normal levels. Inorganic N application did not increase the availability of organic N. Green manuring had a positive effect on soil organic matter. These data indicate that green manuring tropical legumes supply about 30-80 kg commercial N equivalent per ha to the succeeding cereal crops.

## CHAPTER TWO
## POPULATION DYNAMICS OF PLANT PARASITIC NEMATODES IN VARIOUS LEGUME BASED CROPPING SEQUENCES


### Summary

Effects of several tropical legumes on plant parasitic nematode populations and yields of succeeding crops were studied in field plots in 1979, 1980, and 1981. Legumes planted from April to September in one or more seasons were mungbean [*Vigna radiata* (L.) Wilcz.]; 'Norman', 'FL 81d', and 'FL 45a' pigeonpeas [*Cajanus cajan* (L.) Millsp.]; showy crotalaria (*Crotalaria spectabilis* Roth.); slenderleaf crotalaria (*C. brevidens* Benth.); hairy indigo (*Indigofera hirsuta* L.); jointvetch (*Aeschynomene americana* L.); velvetbean [*Mucuna deeringiana* (Bort.) Merr.]; 'Jupiter' soybean [*Glycine max* (L.) Merr.]; alyceclover [*Alysicarpus vaginalis* (L.) DC.]; lablab [*Lablab purpureus* (L.) Sweet.] and sesbania (*Sesbania macrocarpa* Muhl.). Their effects on populations of parasitic nematodes were compared with fallow and 'Cracker Jack' marigold (*Tagetes erecta* L.) in fumigated (with 1,2-dibromoethane) and nonfumigated plots. To estimate the effects of these tropical legumes on nematode populations and the dry matter yields of the succeeding crops, several cereals and legumes were grown in the succeeding fall, winter and spring seasons.

All pigeonpeas, both crotalarias, hairy indigo, jointvetch, velvetbean and marigold reduced root knot nematodes [*Meloidogyne incognita* (Kofoid and White) Chitwood] in each year planted. Fumigation, fallowing, and rotation with jointvetch, hairy indigo, and either crotalaria reduced sting nematode (*Belonolaimus longicaudatus* Rau.) populations.

Rotation with hairy indigo or marigold consistently reduced the lesion nematodes [Pratylenchus brachyurus (Godfrey) Goodey] in all the succeeding crops. Fumigation generally reduced ring nematode (Criconemoides spp.) populations in the succeeding crops. Root knot nematode and the incorporated N had the highest influence on the snap bean dry matter yield. The influence of other nematodes on the snap bean dry matter yield was negligible.

## Introduction

Nematodes, particularly root knot and sting are a major problem in Florida sandy soils. Available nematicides can control most of the nematodes but often the chemical and application costs exceed the crop savings in field crop production.

Rotation of susceptible crops with nematode nonhost or nematode resistant crops has been advised for a long time,as a viable nematode management practice (Watson, 1922). Bakker et al. (1979) reported that several Compositae rapidly kill lesion nematodes [P. penetrans (Cobb) Sher and Allen] with the characteristic α-terthienyl or related compounds available in their roots. Ohbayashi and Chikaoka (1973) reported no increase in P. penetrans for about 400 days on beans, tomato, or Japanese radish grown in soil where marigold had been cultivated. However, it has been very difficult to find successful rotation crops to control root knot nematodes, which have a very wide host range. Also, farmers do not like to waste a growing season on a crop such as marigold which offers no monetary return.

In view of these broad considerations, several tropical legumes and a marigold variety were tested with the dual objectives of enriching the sandy soils with atmospheric N and reducing the nematode populations to safe or minimal levels in the succeeding crops. These studies were carried out under low technology situations with the objectives of limiting fossil fuel energy use in agriculture. The population dynamics of several kinds of plant parasitic nematodes under various cropping sequences were examined.

## Materials and Methods

This 3-year study (1979-81) was conducted at the main agronomy farm, University of Florida, Gainesville. The soil was an Arredondo fine sand (loamy, silicious, hyperthermic, Grossarenic Paleudult). The study was carried out on two proximately located fields: E6 in 1979 and 1981 and S16 in 1980. The 1979 summer experiment was reported earlier (Soffes, 1981[1]). That data are presented here to show the comprehensive picture on tropical legumes. The 1979 experiment was preceded by summer legumes and annual ryegrass (*Lolium multiflorum* L.), the 1980 experiment was preceded by summer soybean *Glycine max* (L.) Merr. , and the 1981 experiment was preceded by summer soybean and winter peas (*Pisum sativum* L.)

The experiments were arranged in a split-plot design with fumigation (F) and nonfumigation (NF) as main plot treatments; crops (listed

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[1]Soffes, A. R. 1981. Legume cover crops selected for high nitrogen yields and their effects on plant-parasitic nematodes. M.S. Thesis, Agronomy Dept., Univ. of Fla., Gainesville, Fla.

Table 2-1. List of crops (sub-plot treatments) in the main summer experiments of 1979, 1980, and 1981.

| Common name | Scientific name | Summer seasons planted |
|---|---|---|
| PI 305070 mungbean | Vigna radiata (L.) Wilcz. | 1979, 1980 and 1981 |
| Pigeonpea cv 'Norman' | Cajanus cajan (L.) Millsp. | 1979, 1980 and 1981 |
| Pigeonpea line 'FL 45a' | Cajanus cajan (L.) Millsp. | 1979 |
| Pigeonpea line 'FL 81d' | Cajanus cajan (L.) Millsp. | 1980 and 1981 |
| Showy crotalaria | Crotalaria spectabilis Roth. | 1979, 1980 and 1981 |
| PI 436527 crotalaria | Crotalaria sp. | 1981 |
| Hairy indigo | Indigofera hirsuta L. | 1979, 1980 and 1981 |
| Jointvetch | Aeschynomene americana L. | 1980 and 1981 |
| Velvetbean | Mucuna deeringiana (Bort.) Merr. | 1979, 1980 and 1981 |
| Alyceclover | Alysicarpus vaginalis (L.) DC. | 1981 |
| Lablab | Lablab purpureus (L.) Sweet. | 1979 |
| Sesbania | Sesbania macrocarpa Muhl. | 1979 |
| Soybean cv 'Jupiter' | Glycine max (L.) Merr. | 1981 |
| Marigold cv 'Cracker Jack' | Tagetes erecta L. | 1980 and 1981 |
| Fallow (bare soil) | | 1979, 1980 and 1981 |

in Table 2-1) and fallow were subplot treatments. Each treatment was replicated 5 times.

At the end of each summer season (September), these legumes were incorporated into the original plots by a series of mechanical and manual operations. In the succeeding seasons several test crops, including snap beans (Phaseolus vulgaris L.) cv 'Blue Lake Bush', corn (Zea mays L.) cv 'Funk G 4507', wheat (Triticum aestivum L.) cv 'FL 301', ryegrass cv 'Florida 80', rye cereal (Secale cereale L.) cv 'Florida Black', and soybean cv 'Williams', were planted in these original legumes plots. The actual summer legumes used in each summer season varied and are presented in Table 2-1. The test crops used after each experiment and their time of planting and harvesting with details of plot arrangement are presented in Fig. 2-1. The soil fumigant, 1,2-dibromoethane (SOILBROM-90®'EDB'), was applied with chisels spaced 30 cm apart and 15 cm below ground at a rate of 65 kg $ha^{-1}$ during the last week of March (3 weeks before planting the summer legumes). In 1979, 12.5 kg N $ha^{-1}$ as ammonium nitrate was applied as a basal dose to the summer legumes. Also in the subsequent spring season, corn planted in the summer lablab plots received 100 kg N $ha^{-1}$ as ammonium nitrate. Other treatments did not receive any N fertilizer. In 1980 and 1981, no N fertilizer was applied either to the summer legumes or to the following crops with the exception of 60 kg N $ha^{-1}$ in the form of ammonium nitrate to marigold in 1980. Recommended P and K fertilizers and water were supplied to all treatments. The fields were kept weed-free by hand hoeing and glyphosate (ROUNDUP®) was applied when necessary at the recommended level to keep the fallow treatment weed-free.

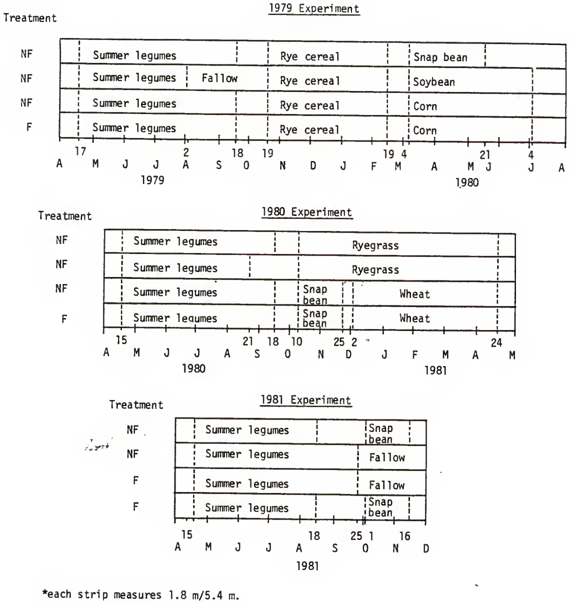



Fig. 2-1. Planting and harvesting dates and pattern of cropping sequences of 1979, 1980, and 1981 experiments.

The experimental sites were naturally infected with root knot, sting, lesion, and ring nematodes. Soil samples (20 cores up to 20 cm deep) for nematode assays were collected and mixed thoroughly; 100 cc subsample was processed using a centrifugal-flotation method (Ayoub, 1977). In case of roots, 10 g fresh roots were processed using a modified Baermann funnel method (Ayoub, 1977). All the parasitic nematodes that were in the sample were counted. Fifteen to twenty plants were randomly selected from each plot for root knot nematode gall ratings. Root knot nematode galls were washed in tap water and indexed on a 0-4 scale; 0 = no galls, 1 = 1-25, 2 = 26-50, 3 = 51-75, and 4 = 76-100 percent root surface galled.

Due to large variations in the nematode population of the same treatment in different replicates, square root transformed data [square root (x+0.50), where x = individual observed value] were used for analysis of variance tests (LeClerg et al., 1962). Interpretations are based on this transformed data but the actual observed data are presented in the text. Regression analysis was performed using nematode populations of snap bean 45 days after planting and the N contribution from the preceding tropical legumes as independent variables and snap bean dry matter yield 45 days after planting as the dependent variable.

## Results and Discussion

Root knot, sting, lesion and ring nematodes were prevalent in the study area and their dynamics in different cropping sequences are discussed. Based on the 3-year results presented in the sampling sequence, discussions are drawn separately for each of the summer crops.

Root Knot Nematodes

1979 experiment

The initial soil sample taken when planting the summer legumes (9 Apr. 1979) did not show any significant differences among the treatments and the root knot nematode counts ranged from 0 to 21 per 100 cc soil.

Root knot nematode counts were taken from soil (Table 2-2) and roots (Table 2-3) on the 88th and 146th day after planting. The data indicated that mungbean, lablab and sesbania were highly susceptible to root knot nematodes. However, the population counts of root knot nematodes from the fumigated plots on the 88th day after planting were significantly lower than from the nonfumigated plots (Tables 2-2 and 2-3). By the 146th day, the fumigated plots of mungbean had approximately the same number of root knot nematodes as the nonfumigated plots.

Following the summer legumes, rye was planted in the fall season. Root knot nematodes were monitored 50 and 121 days after planting; counts were very low (0-45/100 cc soil and no nematodes in the roots) and were not significantly different among the treatments.

Following the rye, snap bean, soybean, and corn were planted in the spring season. The root knot nematodes were monitored at harvest of each of these crops; data from corn and snap bean plots are presented in Table 2-2. The data indicate that corn planted in the summer fallow, mungbean and 45a pigeonpea had significantly higher numbers of root knot nematodes than corn planted in the other summer crop treatments. The differences between fumigated and nonfumigated plots were not significant. Snap bean planted in the nonfumigated summer fallow, mungbean,

Table 2-2. Root knot nematode populations in summer green manure crops and in the succeeding season crops (in soil), 1979.

| | Summer green manure crops | | | | Spring | | | |
|---|---|---|---|---|---|---|---|---|
| | 88 days after planting | | 146 days after planting | | Corn 135 days after planting | | | Snap bean 77 days after planting |
| Crop | F† | NF‡ | F | NF | F | NF | Mean | NF |
| | Root knot nematodes/100 cc soil | | | | | | | |
| Fallow | 2 c§ | 35 bc | 8 d | 28 cd | 180 | 200 | 190 a | 580 a |
| Mungbean | *23 b | 660 a | *2130 a | 1050 b | 82 | 230 | 150 a | 690 a |
| 45a pigeonpea | 1 c | 2 c | 3 c | 7 d | 170 | 180 | 180 a | 240 b |
| Norman pigeonpea | 0 c | 4 c | 1 d | 4 d | 0 | 42 | 21 b | 220 b |
| Showy crotalaria | 0 c | 7 c | 0 d | 10 d | 0 | 22 | 11 b | 160 b |
| Hairy indigo | 0 c | 6 c | 7 d | 30 cd | 2 | 2 | 2 c | 58 c |
| Lablab | *3 c | 120 b | *180 c | 830 b | - | - | - | 260 ab |
| Sesbania | 190 a | 280 b | *890 b | 1890 a | - | - | - | 340 a |
| Velvetbean | 0 c | 3 c | *24 d | 260 c | 0 | 0 | 0 c | 150 b |

†F = Plot treated before the summer legume planting with 1,2-dibromoethane.
‡NF = Nonfumigated.
*For each sampling date, means in the same row marked with an asterisk are significantly different at 5% level according to Duncan's Multiple Range Test.
§Means in the same column not marked with the same lower case letter are significantly different at 5% level according to Duncan's Multiple Range Test.

Table 2-3. Root knot nematode populations in summer green manure crops and in the succeeding season crops, 1979.

| | Summer green manure crops | | | |
|---|---|---|---|---|
| | 88 days after planting | | 146 days after planting | |
| Summer crop | F† | NF‡ | F | NF |
| | —— Root knot nematodes/10 g fresh roots —— | | | |
| Fallow | -- | -- | -- | -- |
| Mungbean | *750 a§ | 4000 a | 2530 a | 2690 b |
| FL 45a pigeonpea | 0 c | 30 b | 30 d | 0 e |
| Norman pigeonpea | 0 c | 0 b | 0 d | 160 de |
| Showy crotalaria | 0 c | 0 b | 0 d | 180 de |
| Hairy indigo | 0 c | 40 b | 10 d | 230 de |
| Lablab | 0 c | 30 b | *260 c | 4270 a |
| Sesbania | *190 b | 3210 a | 1500 b | 650 cd |
| Velvetbean | 40 c | 0 b | *40 d | 2060 bc |

†F = Plot treated before the summer legume planting with 1,2-dibromoethane.

‡NF = Nonfumigated.

*For each sampling date, means in the same row marked with an asterisk are significantly different at 5% level according to Duncan's Multiple Range Test.

§Means in the same column not marked with the same lower case letter are significantly different at 5% level according to Duncan's Multiple Range Test.

lablab, and sesbania had significantly higher numbers of root knot nemtodes than snap bean planted in the other summer crop treatments. Snap bean planted in the nonfumigated hairy indigo plots had fewest root knot nematodes. Soybean planted in all the nonfumigated summer legumes plots had very few or no root knot nematodes.

1980 experiment

During the summer legumes' growth period, soil samples were taken at 0 (pre-plant), 45, 135, and 155 days after planting. At all the samplings, no significant root knot nematode population differences were observed among the treatments. Very few root knot nematodes were recovered at any sampling of any crop, except 154 root knot nematodes/100 cc soil from mungbean plots (135th day sample).

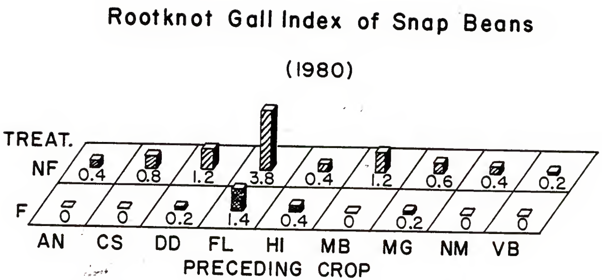
In the succeeding fall season, snap beans were grown in the summer legumes incorporated plots. At the snap bean harvest, there were very few root knot nematodes in the soil; differences among the treatments were not significant. Root knot nematodes in the roots (Table 2-4) and the gall indices on the roots (Fig. 2-2) differed significantly among the treatments. Snap bean planted behind summer fallow and mungbean had significantly higher numbers of root knot nematodes than when planted behind the other summer crops.

In the succeeding winter season (after harvesting snap beans), wheat and ryegrass were planted in the same plots. Soil and root samples taken at the harvest stage of these two crops showed no root knot nematode infestations.

Table 2-4. Root knot nematode populations in snap bean roots, 1980.

| Crop | Fall snap bean 45 days after planting F† | NF‡ | Mean |
|---|---|---|---|
| | Root knot nematodes/10 g fresh roots | | |
| Fallow | 1 | 31 | 16 b§ |
| Mungbean | 87 | 450 | 270 a |
| Marigold | 0 | 17 | 9 b |
| FL 81d pigeonpea | 0 | 11 | 6 b |
| Norman pigeonpea | 4 | 1 | 3 b |
| Showy crotalaria | 0 | 55 | 28 b |
| Jointvetch | 0 | 1 | 1 b |
| Hairy indigo | 0 | 27 | 14 b |
| Velvetbean | 3 | 0 | 2 b |

†F = Plot treated before the summer legume planting with 1,2-dibromoethane.
‡NF = Nonfumigated.
§Means in the same column not marked with the same lower case letter are significantly different at 5% level according to Duncan's Multiple Range Test.




Note[1]: Crop acronyms - AN = jointvetch, CS = showy crotalaria, DD = FL 81d pigeonpea, FL = fallow, HI = hairy indigo, MB = mungbean, MG = marigold, NM = Norman pigeonpea and VB = velvetbean.

Note[2]: Treatment acronyms - F = fumigated, NF = nonfumigated.

Fig. 2-2. Snap bean root galling as influenced by preceding summer crop and fumigation, 1980.

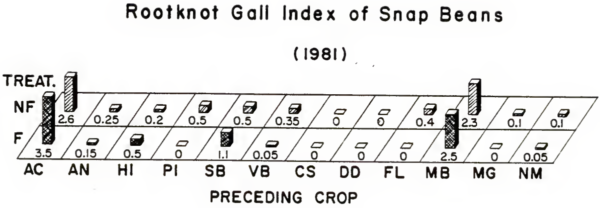
1981 experiment

The pre-plant soil samples had very few root knot nematodes. The soil and root samples taken from green manure crops 70 and 130 days after planting indicated significant treatment differences. Mungbean and alyceclover had significantly more root knot nematodes than the other crops (Tables 2-5 and 2-6). The fumigated alyceclover had significantly higher numbers of root knot nematodes in soil and roots than the nonfumigated alyceclover on the 130th day.

In the succeeding fall season, snap bean was grown in the same plots. Root knot nematode populations in the soil and roots of snap bean were estimated on the 45th day. There were no significant fumigation treatment effects (Tables 2-5 and 2-6) on root knot nematode populations in the soil and roots. Snap bean planted in the summer alyceclover, fallow, mungbean and soybean plots had significantly higher numbers of root knot nematodes in the soil and roots than snap bean planted behind the other summer crop treatments. The root gall indices taken at this stage also confirmed these results (Fig. 2-3). However, snap bean planted in the other summer crop treatments also had root knot nematodes above the economic threshold levels (Tables 2-5 and 2-6).

Population dynamics in cropping systems:

Fallow. Root knot nematodes were present in low numbers in the fallow plots during the summer season but large numbers were prevalent in the succeeding snap bean and corn crops (Tables 2-2, 2-5, and 2-6 and Fig. 2-2). Contrary to these results, Johnson and Campbell (1977) reported that clean fallow was most effective compared to pearl millet, sorghum, soybean, showy crotalaria and Norman pigeonpea in suppressing




Note[1]: Crop acronyms - AC = alyceclover, AN = jointvetch, HI = hairy indigo, PI = slenderleaf crotalaria, SB = soybean, VB = velvetbean, CS = showy crotalaria, DD = FL 81d pigeonpea, FL = fallow, MB = mungbean, MG = marigold, and NM = Norman pigeonpea.

Note[2]: Treatment acronyms - F = fumigated, NF = nonfumigated.

Fig. 2-3. Snap bean root galling as influenced by preceding summer crop and fumigation, 1981.

Table 2-5. Root knot nematode populations in summer green manure crops and in fall snap beans (in soil), 1981.

| Summer crop | Summer green manure crops: 70 days after planting F† | NF‡ | 130 days after planting F | NF | Fall snap beans: 45 days after planting F | NF | Mean |
|---|---|---|---|---|---|---|---|
| | Root knot nematodes/100 cc soil | | | | | | |
| Fallow | 0 b§ | 0 b | 0 b | 0 a | 91 | 320 | 206 ab |
| Mungbean | *39 a | 116 a | 46 b | 21 a | 297 | 290 | 294 ab |
| Marigold | 2 b | 4 b | 0 b | 0 a | 10 | 79 | 45 c |
| FL 81d pigeonpea | 0 b | 0 b | 0 b | 0 a | 40 | 119 | 80 c |
| Norman pigeonpea | 0 b | 0 b | 0 b | 0 a | 96 | 35 | 66 c |
| Showy crotalaria | 0 b | 0 b | 0 b | 0 a | 29 | 59 | 44 c |
| Slenderleaf crotalaria | 1 b | 0 b | 0 b | 0 a | 52 | 126 | 89 c |
| Jointvetch | 0 b | 0 b | 0 b | 0 a | 151 | 121 | 136 bc |
| Hairy indigo | 0 b | 3 b | 0 b | 0 a | 90 | 164 | 127 bc |
| Velvetbean | 0 b | 0 b | 0 b | 0 a | 15 | 110 | 63 c |
| Soybean | 0 b | 0 b | 14 b | 5 a | 176 | 203 | 190 abc |

†F = Plot treated before the summer legume planting with 1,2-dibromoethane.
‡NF = Nonfumigated.
*For each sampling date, means in the same row marked with an asterisk are significantly different at 5% level according to Duncan's Multiple Range Test.
§Means in the same column not marked with the same lower case letter are significantly different at 5% level according to Duncan's Multiple Range Test.

Table 2-6. Root knot nematode populations in summer green manure crops and in fall snap beans (in roots), 1981.

| Summer crop | Summer green manure crops: 70 days after planting | | Summer green manure crops: 130 days after planting | | Fall snap beans: 45 days after planting | | |
|---|---|---|---|---|---|---|---|
| | F† | NF‡ | F | NF | F | NF | Mean |
| | Root knot nematodes/10 g fresh roots | | | | | | |
| Fallow | -- | -- | -- | -- | 820 | 3040 | 1930 bc |
| Mungbean | *49 a§ | 92 a | 58 b | 18 a | 7530 | 4060 | 5800 a |
| Marigold | 0 b | 26 b | 0 c | 0 a | 20 | 510 | 270 d |
| FL 81d pigeonpea | 0 b | 0 b | 0 c | 0 a | 430 | 830 | 630 bcd |
| Norman pigeonpea | 0 b | 0 b | 0 c | 0 a | 600 | 340 | 470 cd |
| Showy crotalaria | 0 b | 0 b | 0 c | 0 a | 410 | 120 | 260 d |
| Slenderleaf crotalaria | 0 b | 0 b | 0 c | 0 a | 510 | 710 | 610 bcd |
| Jointvetch | 0 b | 0 b | 0 c | 0 a | 560 | 1220 | 890 bcd |
| Hairy indigo | 0 b | 0 b | 0 c | 0 a | 940 | 310 | 820 bcd |
| Velvetbean | 0 b | 0 b | 0 c | 0 a | 1150 | 450 | 800 bcd |
| Soybean | 0 b | 0 b | 10 c | 13 a | 2760 | 1000 | 1880 b |
| Alyceclover | 0 b | 0 b | *128 a | 9 a | 8360 | 4540 | 6460 a |

†F = Plot treated before the summer legumes planting with 1,2-dibromoethane.
‡NF = Nonfumigated.
*For each sampling date, means in the same row marked with an asterisk are significantly different at 5% level according to Duncan's Multiple Range Test.
§Means in the same column not marked with the same lower case letter are significantly different at 5% level according to Duncan's Multiple Range Test.

numbers of root knot nematodes up to 2 years. However, fallow lost its effectiveness even in conjunction with granular fensulfothion after 2 years. Murphy et al. (1974) also reported that fallowing was very effective in suppressing M. incognita populations. However, in our experiment, fallowing did not have any adverse effects on the root knot nematodes in the succeeding season, and, therefore, raised questions about the value of fallowing for control of root knot nematodes.

Mungbean, alyceclover, sesbania and lablab. Mungbean and alyceclover were the best root knot nematode hosts among the crops tested; however, sesbania and lablab were also infected with large numbers of root knot nematodes during their growing season (Tables 2-2, 2-3, 2-5, and 2-6 and Figs. 2-2 and 2-3). Corn and snap bean planted behind these crops in the succeeding seasons had high nematode counts. Fumigation did not adequately control the root knot nematodes in these susceptible crops but it did help establish better plant stands of these crops than grew in nonfumigated plots. That may be the reason for higher numbers of root knot nematodes in the fumigated plots than in nonfumigated plots later in the growing season (Tables 2-2, 2-5, and 2-6).

In India, Alam et al. (1977) reported that mungbean (local cultivar) had decreased considerably the M. incognita juveniles in their cropping sequences trial. This may reflect variation in M. incognita races between their experiment and our experiment. This may also indicate that root knot nematode resistance genes are available in this crop and need to be considered in the breeding programs. Because of the high root knot nematode susceptibility of these crops even under fumigation, they need to be avoided as much as possible in multiple cropping systems.

Soybean. Jupiter soybean had few root knot nematodes during its growing period (Tables 2-5 and 2-6). However, the snap bean planted in the succeeding fall season had very high numbers of root knot nematodes. The root knot nematode populations on the snap bean planted in the summer soybean plots were significantly lower than the populations obtained from snap bean planted in the summer mungbean and alyceclover plots and significantly higher than the populations obtained from the snap bean planted in plots from the other summer crop treatments.

Trabulsi et al. (1980) reported that Jupiter soybean is moderately resistant to *M. incognita* in comparison to two other soybean cultivars, Cobb and IAC-2. In this experiment, the Jupiter soybean post-incorporation effect on the root knot nematodes was in the intermediate range among the tropical legumes. Therefore, this crop cannot be suggested as a choice crop to have in the rotations in areas with high root knot nematode problems.

Marigold. Marigold with and without fumigation had very low numbers of root knot nematodes during their growth period (Tables 2-5 and 2-6). The number of root knot nematodes in the fall season snap bean planted in the summer marigold plots were substantially lower than the root knot nematodes obtained from snap bean planted in the other summer crop treatments (Tables 2-4, 2-5, 2-6, and Figs. 2-2 and 2-3). Fumigated marigold plots supported fewer root knot nematodes than nonfumigated plots (Tables 2-5 and 2-6, and Figs. 2-2 and 2-3). Similarly, Miller (1977) reported that in greenhouse tests, tobacco, tomato, potato, petunia and zinnia grew better in soil from marigold plots or fumigated soil than fallowed or nonfumigated soil.

Pigeonpea, crotalaria, hairy indigo, jointvetch and velvetbean. Pigeonpea (cvs 81d and Norman), crotalaria, hairy indigo, jointvetch, and velvetbean had significantly fewer root knot nematodes during their summer growth period than other crop treatments (Tables 2-2, 2-3, 2-5, and 2-6). Subsequent crops of corn (Table 2-2), wheat, ryegrass, rye cereal, snap bean (Tables 2-4, 2-5, 2-6, and Figs. 2-2 and 2-3) and soybean also had significantly fewer root knot nematodes in 1979, 1980, and 1981 experiments. The suppressive effects of these legumes on root knot nematodes in 1981 fall snap bean was significantly greater than the other summer legumes. However, the number of root knot nematodes which survived were sufficient to cause significant yield reductions in the test crop (Table 2-6). This happened only in 1981, probably because of the highly root knot susceptible peas grown on the experimental site during the 1980-81 winter season.

These crops eliminated or reduced to safe levels the root knot nematodes in the years or situations that had lower initial populations. Where initial populations of nematodes were quite high, they only partially reduced the nematode populations. Johnson and Campbell (1977) reported that as the number of nematodes increased, neither the summer cover crops (millet, milo, soybean, crotalaria and Norman pigeonpea) nor the nematicide (fensulfothion) completely controlled nematodes. Their results very much agree with ours in these experiments. In the succeeding fall crop season, fumigation in the early spring did not reduce the root knot nematodes more than pigeonpea, crotalaria, hairy indigo, jointvetch and velvetbean.

Sting Nematode

1979 experiment

Very few or no (0-5/100 cc soil) sting nematodes were found in all the green manure plots and in the succeeding crops (rye, corn snap bean, and soybean). There were no significant differences among the treatments.

1980 experiment

Sting nematode populations in the green manure crops and in the succeeding season crops (snap bean, wheat, and ryegrass) are presented in Table 2-7. These data indicate that fumigation with EDB, in the beginning of the summer season (prior to green manure planting), had controlled the sting nematodes in all the green manure crops and in the succeeding season snap bean, wheat and rye planted in these original plots. During the green manure crops' growth period, the two pigeonpea cultivars (81d and Norman) showed signficantly higher sting nematode populations than the other crops. By the end of the growing season, mungbean and marigold also had significantly higher numbers of sting nematodes. Out of the three succeeding seasons' crops, wheat and ryegrass had higher sting nematode populations than snap bean. Wheat and ryegrass planted in the summer mungbean, marigold, 81d pigeonpea, Norman pigeonpea and velvetbean plots had significantly higher sting nematode populations than when planted behind other summer crops (Table 2-7).

1981 experiment

Sting nematode populations were very few or negligible in the green manure crops and in the following snap bean. Of the four soil samples taken (pre-plant, 70 and 130 days after planting green manure crops and

Table 2-7. Sting nematode populations in summer green manure crops and in following crops, 1980.

| Crop | Summer green manure crops | | | | | | | | Snap bean | | Wheat | Ryegrass |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | pre-plant | | 45 days after planting | | 135 days after planting | | 155 days after planting | | 45 days after planting | | 142 days after planting | 194 days after planting |
| | F† | NF‡ | F | NF | F | NF | F | NF | F | NF | NF | NF |
| | Sting nematodes/100 cc soil | | | | | | | | | | | |
| Fallow | 0 a§ | 4 a | 0 a | 3 a | 0 a | 0 c | 0 b | 0 a | 0 c | 1 a | 4 bc | 2 b |
| Mungbean | 6 a | 42 a | 6 a | 4 a | *1 a | 18 b | 13 ab | *0 a | 12 a | *0 a | 9 bc | 25 a |
| Marigold | 0 a | 2 a | 0 a | 3 a | 0 a | 9 bc | 9 ab | 0 a | 4 ab | 5 a | 15 ab | 18 ab |
| FL 81d pigeonpea | 0 a | 11 a | 0 a | 0 a | *0 a | 45 a | 11 ab | 0 a | 1 c | *0 a | 25 a | 13 b |
| Norman pigeonpea | 6 a | 10 a | 0 a | 4 a | *0 a | 45a | 21 a | *0 a | 7 ab | *3 a | 15 ab | 35 a |
| Showy crotalaria | 0 a | 8 a | 0 a | 4 a | 0 a | 1 c | 0 b | 10 a | 0 c | 0 a | 0 c | 5 b |
| Hairy indigo | 0 a | 18 a | 1 a | 4 a | 0 a | 0 c | 0 b | 0 a | 1 c | 0 a | 6 bc | 10 b |
| Jointvetch | 0 a | 25 a | 0 a | 3 a | 0 a | 3 bc | 2 b | 0 a | 3 ab | 2 a | 8 bc | 7 b |
| Velvetbean | 0 a | 21 a | 0 a | 1 a | 0 a | 6 bc | 0 b | 0 a | 0 c | *0 a | 14 ab | 18 ab |
| Mean | *1.3 | 15.7 | 0.8 | 2.9 | 0 | 14 | 6.4 | 1.1 | 3.1 | 1.2 | 10.7 | 14.8 |

†F = Plot treated before the summer legume planting with 1,2-dibromoethane.
‡NF = Nonfumigated.
*For each sampling date, means in the same row marked with an asterisk are significantly different at 5% level according to Duncan's Multiple Range Test.
§Means in the same column not marked with the same lower case letter are significantly different at 5% level according to Duncan's Multiple Rante Test.

on the 45th day of snap bean crop), only the third (130 days) showed significant differences in sting nematode populations among treatments (Table 2-8).

The third soil sample indicated that Jupiter soybean grown under nonfumigated conditions was highly susceptible to sting nematodes.

Population dynamics in cropping systems

The differences in the level of sting nematode populations among the 3 years could be attributed to the differences in the initial populations of the two experimental sites (1979 and 1981 experiments were conducted on the same site, E6, while the 1980 experiment was conducted on a different site, S16).

Fumigation, in general, reduced sting nematode populations to negligible numbers in all crops. In nonfumigated plots of FL 81d pigeonpea, Norman pigeonpea, and Jupiter soybean, sting nematode populations increased from negligible numbers at planting to very high numbers by the end of the growing season. Sting nematode populations decreased under mungbean but the numbers were above safe levels throughout the growing season. All the other crops were nonhosts to sting nematode (Tables 2-7 and 2-8).

The following (succeeding summer green manuring) snap bean crop had few sting nematodes. This could be due to the scarcity of healthier root tips to feed on as a consequence of severe damage by the endoparasitic nematodes.

Fumigation with 1,2-dibromoethane, fallowing and rotation with jointvetch or hairy indigo or showy crotalaria or slenderleaf crotalaria are good choices to reduce sting nematode populations. Overman (1969)

Table 2-8. Sting nematode populations in the summer green manure crops, 1981.

| Crop | Summer green manure crops 130 days after planting F† | NF‡ |
|---|---|---|
| | Sting nematodes/100 cc soil | |
| Fallow | 1 b§ | 0 b |
| Mungbean | 0 b | 0 b |
| Marigold | 1 b | 1 b |
| FL 81d pigeonpea | 1 b | 1 b |
| Norman pigeonpea | 0 b | 4 b |
| Showy crotalaria | 0 b | 0 b |
| Slenderleaf crotalaria | 1 b | 0 b |
| Jointvetch | 0 b | 0 b |
| Hairy indigo | 0 b | 0 b |
| Velvetbean | 0 b | 0 b |
| Soybean | *2 b | 46 a |
| Alyceclover | 5 a | 4 b |

†F = Plot treated before the summer legume planting with 1,2-dibromoethane.
‡NF = Nonfumigated.
*For each sampling date, means in the same row marked with an asterisk are significantly different at 5% level according to Duncan's Multiple Range Test.
§Means in the same column not marked with the same lower case letter are significantly different at 5% level according to Duncan's Multiple Range Test.

reported that a summer crop of hairy indigo decreased sting nematode populations in chrysanthemum fields.

## Lesion Nematodes

### 1979 experiment

No lesion nematodes were recoverd from samples before planting in the experimental site. There were negligible numbers of lesion nematodes (0-5/100 cc soil) in soil samples taken after planting. The root samples taken on the same day from legumes in nonfumigated plots had significantly more lesion nematodes than in fumigated plots (Table 2-9). In soil samples taken 146 days after planting, showy crotalaria had significantly more lesion nematodes than crops in nonfumigated plots (Table 2-9). Lesion nematode populations in root samples taken on the same day did not differ significantly among crops (Table 2-9).

Following the summer legumes, rye was planted in the fall season. Numbers of lesion nematodes 50 days (soil) and 121 days (soil and roots) after planting were negligible in the soil samples (0-5/100 cc soil); there were none in the root samples.

Following the rye crop, corn, soybean and snap bean were planted in the spring season in the original summer legume plots. Very few lesion nematodes (0-9/100 cc soil) were found in soil samples taken from these three crop plots at their respective harvest times.

### 1980 experiment

There were 0-7 lesion nematodes/100 cc soil in pre-plant soil samples. Similarly, soil samples taken during the summer (45, 135, and 155 days after planting) contained very few lesion nematodes (0-20/100 cc

Table 2-9. Lesion nematode populations in summer green manure crops, 1979.

| | Summer green manure crops | | | | | |
|---|---|---|---|---|---|---|
| | 88 days after planting | | 146 days after planting | | | |
| | F† | NF‡ | F | NF | F | NF |
| | Nematodes/10 g fresh roots | | Nematodes/100 cc soil | | Nematodes/10 g fresh roots | |
| Fallow | -- | -- | 0 a | 1 b | -- | -- |
| Mungbean | 0 a§ | 2090 a | 7 a | 0 b | 10 a | 190 a |
| FL 45a pigeonpea | 0 a | 60 a | 0 a | 5 b | 20 a | 10 a |
| Norman pigeonpea | 0 a | 280 a | 1 a | 5 b | 10 a | 30 a |
| Showy crotalaria | 30 a | 130 a | *0 a | 97 a | 0 a | 310 a |
| Hairy indigo | 0 a | 0 a | 0 a | 3 b | 10 a | 40 a |
| Lablab | 0 a | 150 a | 3 a | 1 b | 10 a | 20 a |
| Sesbania | 10 a | 160 a | 0 a | 4 b | 10 a | 0 a |
| Velvetbean | 0 a | 60 a | 0 a | 0 b | 0 a | 170 a |
| Mean | *4.4 | 325 | 1.2 | 12.7 | 7.0 a | 85.6 a |

†F = Plot treated before the summer legumes planting with 1,2-dibromoethane.
‡NF = Nonfumigated.
*For each sampling date, means in the same row marked with an asterisk are significantly different at 5% level according to Duncan's Multiple Range Test.
§Means in the same column not marked with the same lower case letter are significantly different at 5% level according to Duncan's Multiple Range Test.

soil). Only samples taken 135 days after planting had significant differences in lesion nematode populations among treatments (Table 2-10). Showy crotalaria and velvetbean plots had significantly higher numbers of lesion nematodes than other plots. Summer crops in fumigated plots had significantly lower numbers of lesion nematodes than the same crops grown in nonfumigated plots.

Following the summer green manure crops, snap bean was grown in the fall season. The lesion nematode populations in soil and roots were estimated 45 days after planting. No lesion nematodes were recovered from soil from any of the treatments. However, some treatments had many more lesion nematodes in roots than had others (Table 2-10). Fumigation treatments had significantly fewer lesion nematodes than nonfumigated treatments. Snap bean planted following velvetbean had significantly higher numbers of lesion nematodes in roots than when planted after fallow, marigold, Norman pigeonpea, or hairy indigo.

Following fall snap bean, wheat and ryegrass were planted in the winter season; very few (0-6/100 cc soil) lesion nematodes were found in the soil samples taken at crop maturity and none were recovered from roots.

1981 experiment

Soil samples taken pre-planting and 70 and 130 days after summer legume planting indicated no significant treatment effects on lesion nematodes; populations ranged from 0-12/100 cc soil. There were no significant differences among treatments in numbers of lesion nematodes in root samples taken 70 days after planting summer legumes; populations were 0-269/10 g fresh roots. There were significantly fewer lesion

Table 2-10. Lesion nematode populations in summer green manure crops and in fall snap beans, 1980.

| Summer crop | Summer green manure crops 135 days after planting | | Snap beans 45 days after planting | | |
|---|---|---|---|---|---|
| | F† | NF‡ | F | NF | Mean |
| | Lesion nematodes/100 cc soil | | Lesion nematodes/10 g fresh roots | | |
| Fallow | 0 a§ | 3 b | 15 | 124 | 70 b |
| Mungbean | 0 a | 0 b | 69 | 643 | 356 ab |
| Marigold | 0 a | 0 b | 2 | 398 | 200 b |
| FL 81d pigeonpea | 0 a | 3 b | 74 | 335 | 205 ab |
| Norman pigeonpea | 0 a | 0 b | 10 | 332 | 171 b |
| Showy crotalaria | *0 a | 13 ab | 1 | 865 | 433 ab |
| Hairy indigo | 1 a | 0 b | 6 | 196 | 101 b |
| Jointvetch | 0 a | 1 b | 16 | 502 | 259 ab |
| Velvetbean | *0 a | 20 a | 120 | 1261 | 691 a |
| Mean | | | *35 | 517 | |

†F = Plot treated before the summer legume planting with 1,2-dibromoethane.
‡NF = Nonfumigated.
*For each sampling date, means in the same row marked with an asterisk are significantly different at 5% level according to Duncan's Multiple Range Test.
§Means in the same column not marked with the same lower case letter are significantly different at 5% level according to Duncan's Multiple Range Test.

nematodes in root samples from fumigated plots taken on all crops 130 days after planting than in nonfumigated soil. Under nonfumigated conditions, showy crotalaria, slenderleaf crotalaria, soybean and alyceclover had significantly higher numbers of lesion nematodes than the other crops. In fumigated plots, the populations were generally low in all the crops; jointvetch, velvetbean, slenderleaf crotalaria, showy crotalaria, Norman pigeonpea and mungbean had significantly higher numbers of lesion nematodes than the other crops (Table 2-11).

Following summer legumes, snap bean was grown in the fall season. There were no significant differences among treatments in lesion nematodes in soil and root samples 45 days after planting snap bean. Populations in the soil were low (0-14/100 cc soil) and those in the roots were high (Table 2-11) but not significantly different, due to high variability in the data.

Population dynamics in the cropping systems

There were few or no lesion nematodes in most soil samples during the 3 years (Tables 2-9 and 2-10). Populations in roots were often high and highly variable. Fumigation prior to summer legume planting significantly reduced the lesion nematodes in the summer green manure crops but not in the succeeding snap bean crop. Rotation with hairy indigo and marigold significantly reduced lesion nematodes in the succeeding seasons crops compared to the other summer rotation crops.

## Ring Nematodes

Ring nematode populations were monitored in all 3 years. The populations were highly variable and the crop treatment differences

Table 2-11. Lesion nematodes in summer green manure crops and in fall snap beans, 1981.

| Summer crop | Summer green manure crops 130 days after planting F† | NF‡ | Fall snap bean 45 days after planting F | NF |
|---|---|---|---|---|
| | Lesion nematodes/10 g fresh roots | | | |
| Fallow | -- | -- | 59 a | 290 a |
| Mungbean | 20 abc§ | 54 cde | 1 a | 210 a |
| Marigold | 0 c | 0 f | 5 a | 46 a |
| FL 81d pigeonpea | 0 c | 22 def | 280 a | 24 a |
| Norman pigeonpea | 14 abc | 54 cde | 47 a | 990 a |
| Showy crotalaria | 18 abc | 500 a | 2200 a | 68 a |
| Slenderleaf crotalaria | 40 abc | 180 b | 40 a | 53 a |
| Jointvetch | 66 a | 1 f | 38 a | 300 a |
| Hairy indigo | 0 c | 9 ef | 9 a | 4 a |
| Velvetbean | 47 ab | 21 def | 72 a | 290 a |
| Soybean | 0 c | 140 bc | 410 a | 260 a |
| Alyceclover | 0 c | 81 bcd | 78 a | 360 a |
| Mean | *23 | 117 | 359 | 321 |

†F = Plot treated before the summer legume planting with 1,2-dibromoethane.
‡NF = Nonfumigated.
*For each sampling date, means in the same row marked with an asterisk are significantly different at 5% level according to Duncan's Multiple Range Test.
§Means in the same column not marked with the same lower case letter are significantly different at 5% level according to Duncan's Multiple Range Test.

were always nonsignificant; hence, the data are not presented here. There generally were fewer ring nematodes in fumigated plots than in nonfumigated plots.

Nitrogen and Nematode Influence on Snap Bean Yield

Snap bean, highly susceptible to root knot nematode, was used as a test crop in all the 3 study years to determine the effectiveness of summer legumes in reducing the root knot and other nematodes in the succeeding crops.

Considering snap bean dry matter yield as the dependent variable and nematode populations (soil root knot, roots root knot, soil sting, soil lesion, root lesion and soil ring) and incorporated organic N (in the form of green manure) as independent variables, a regression ($R^2$) procedure was carried out as described in Statistical Analysis System (SAS) package (Goodnight, 1979). Root knot nematode and incorporated green manure N had the highest influence on snap bean dry matter yield (Table 2-12). The influence of sting, lesion and ring nematodes was negligible.

The best models for the effects of root knot nematode and green manure N on snap bean dry matter yield in 1980 are presented in Table 2-13 and the 1981 models are presented in Figs. 2-4, 2-5, and 2-6. These indicate that snap bean dry matter yield increased linearly with increasing amounts of green manure N incorporated before planting and decreased in proportion to the numbers of root knot nematodes infecting it or its soil (Figs. 2-4, 2-5, 2-6, and Table 2-13).

Table 2-12. Coefficients of determination ($R^2$) of nematode populations and green manure nitrogen on snap bean dry matter yield in 1980 and 1981.

| | R-square | |
|---|---|---|
| Variable in model | 1980 | 1981 |
| Root knot in soil (x1) | 0.20 | 0.50 |
| Root knot in root (x2) | 0.24 | 0.39 |
| Sting (x3) | 0.11 | 0.03 |
| Lesion in soil (x4) | 0.03 | 0.06 |
| Lesion in root (x5) | 0.04 | 0.08 |
| Ring (x6) | 0.00 | 0.01 |
| Organic nitrogen (x7) | 0.51 | 0.52 |
| x1x2 | 0.24 | 0.51 |
| x4x5 | 0.12 | 0.14 |
| x1x2x3 | 0.25 | 0.51 |
| x1x2x7 | 0.58 | 0.64 |
| x4x5x7 | 0.64 | 0.58 |
| x1x2x4x5 | 0.33 | 0.56 |
| x1x2x3x4x5x6x7 | 0.68 | 0.70 |

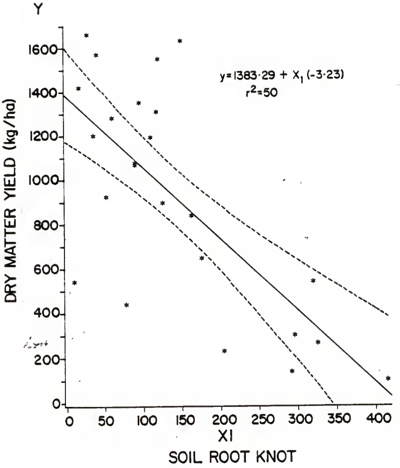



Fig. 2-4. Relationship of harvest time root knot nematode populations in the soil to the dry matter yield of snap bean.

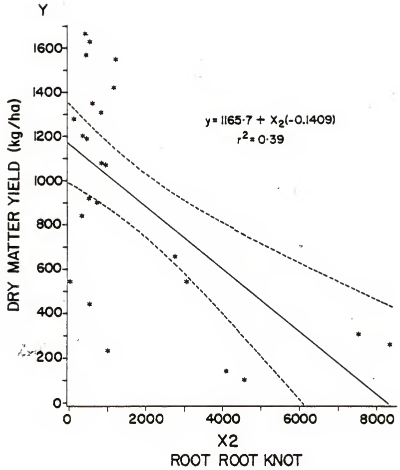



Fig. 2-5. Relationship of harvest time root knot nematode populations in the roots to the dry matter yield of snap bean.

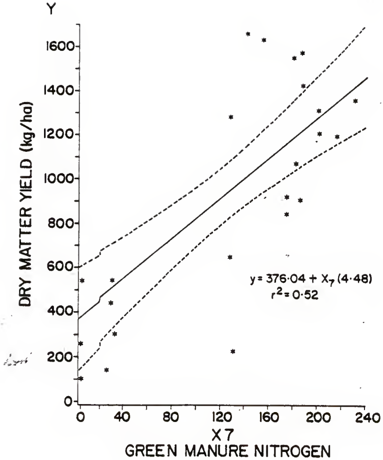



Fig. 2-6. Relationship of amount of pre-plant green-manured nitrogen to the dry matter yield of snap bean.

Table 2-13. The best-fit regression models of root knot nematode, and organic nitrogen with snap bean dry matter yield in 1980.

| Variable | | R-square |
|---|---|---|
| Root knot in soil | $424.87+X_1(100.15)+(x_1^2)(-634.51)+(x1)(382.53)+(x_1^4)(-34.85)$ | 0.53 |
| Root knot in root | $415.52 + X2(-0.56)$ | 0.24 |
| Organic nitrogen | $268.07+x_7(1.15)$ | 0.51 |

Higher root knot populations and the lower green manure N had very significant adverse effects on the snap bean dry matter yield. This could be explained by two theories. The first theory is that the lower N availability results in less vigorous snap bean seedlings which consequently offer poor resistance to root knot nematode infection. The second theory is that the heavy root knot infection resulted in poorly functioning self-feeding mechanism (nitrogen fixation) of snap bean which consequently resulted in less vigor and more susceptibility to root knot nematodes. The cause and effect of these two possible happenings in snap bean cannot be identified. Primavesi and Primavesi (1973) reported that nematode infection will not reduce the yield of maize and soybean in tropics if adequate fertilizer is applied. The conclusion of these theories is that adequate supply of N to legumes might help in reducing the root knot nematode damage.

The use of selected green-manured legumes annually in a multiple-cropping system should lead to both biological control of parasitic nematodes and sizeable quantities of biologically-fixed N being made available to non-green manure crops in the cropping system. This could lead to high crop yields with low N fertilizer and no fumigation. Research should be initiated on the feasibility of such low-input cropping systems.

## Conclusions

Of the four problem nematodes observed in the experiments, root knot nematodes had the most adverse effects on the critical test crop, snap bean. Of the 11 legume species tested, at least five of them were

nonhosts to root knot nematodes and their effectiveness in reducing root knot nematodes in the following crops was better than summer fumigation. Hairy indigo reduced sting and lesion nematodes in addition to root knot nematodes in the succeeding crops indicating the possibility of effective endo and ecto parasitic nematode control by rotating with this crop.

# CHAPTER THREE
# EFFECT OF SOIL FUMIGATION ON NITROGENASE ACTIVITY ($C_2H_2$ REDUCTION) OF TROPICAL LEGUMES


## Summary

Nine tropical legume cultivars were grown for two seasons to compare N fixation rates and determine whether soil fumication affected acetylene reduction (AR) activity. Highest rates of AR were found with jointvetch (*Aeschynomene americana* L.), alyceclover (*Alysicarpus vaginalis* (L.) DC. , soybean [*Glycine max* (L.) Merr.] cv 'Jupiter', and slenderleaf crotalaria (*Crotalaria brevidens* Benth.). Soil fumigation influenced AR but the effect was not consistent either with the time of sampling or with the crop. Nitrogen fixation estimated by AR was lower than indicated by micro-Kjeldahl analysis for pigeonpea [*Cajanus cajan* (L.) Millsp.], showy crotalaria (*Crotalaria spectabilis* Roth.), hairy indigo (*Indigofera hirsuta* L.), and velvetbean [*Mucuna deeringiana* (Bort.) Merr.]. The discrepancies apparently result from incomplete recover of nodules on secondary and tertiary roots. This raises questions about the validity of the AR procedure for quantitative estimations of N under field conditions. Acetylene reduction activity was closely correlated with dry weights of nodules in all the crops.


## Introduction

Increased costs of synthetic N fertilizers have prompted renewed interest in biological N fixation as a source of N for food crop production. In the tropics, where fertilizer costs severely limit agricultural

productivity, only a few legumes work well in crop rotation schemes. Most are subject to numerous pest problems, among which nematodes are particularly difficult to control. Nematode populations can be suppressed by cultural practices, such as crop rotation schemes, and by periodic chemical treatments. However, the latter may have unfavorable effects on soil microbial populations, and,therefore, studies on the effect of pesticides on soil microbiological processes are desirable (Alexander, 1969). The fumigation effect on the Rhizobium sp. and its N-fixing process in tropical legumes has not been explored.

There is a clear need for more information about the usefulness of various tropical legumes as N sources and as controllers of nematodes in crop rotations. We compared PI 305070 mungbean [Vigna radiata (L.) Wilcz.], Norman and FL 81d pigeon peas, showy crotalaria, slenderleaf crotalaria, hairy indigo, jointvetch, velvetbean, soybean, and alyceclover, in two plantings as summer green manure crops. Each legume was evaluated with and without 1,2-dibromoethane (SOILBROM-90®'EDB')fumigation. Several of the legumes studied are new introductions to the United States. Some, like hairy indigo and showy crotalaria, are considered to be serious weeds in certain row crops. However, some have performed well as forage crops. In recent studies, pigeonpea has shown ability in Florida to grow well under drought conditions (Prine, 1982 unpublished data) and jointvetch is tolerant of flooded soils (Quesenberry et al., 1982). Thus, both of these vigorous species appear promising as useful crops in rotation schemes under tropical conditions. However, their N fixation rates have been studied very little.

## Materials and Methods

The experiments were conducted at Gainesville, Florida, on Arredondo fine sand (loamy, silicious, hyperthermic Grossarenic Paleudult). Plantings were made on two adjacent fields during the years 1980 and 1981.

All the crops were grown in five replications on fumigated and nonfumigated main plots of a split-plot design set up in summer seasons of 1980 and 1981. To fumigate the soil, EDB was applied at the rate of 65 kg $ha^{-1}$ by injecting the material 15 cm below ground by chisels in rows 30 cm apart. The experimental sites were well inoculated with cowpea- and soybean-type Rhizobium from previous cropping. A basal application of 500 kg $ha^{-1}$ of 0-10-20 ($N$-$P_2O_5$-$K_2O$) fertilizer was applied each season. Acetylene reduction activity was determined by the procedure of Hardy et al. (1973). In 1980, AR measurements were made on nonfumigated jointvetch, showy crotalaria and hairy indigo and in 1981, the measurements were taken on all the legumes except alyceclover under fumigated and nonfumigated conditions. Rates were determined three times for each crop, within the 150 days growth period (green manured after that) in order to identify periods of greatest activity. Sampling dates are shown in Table 3-3. The dates were not the same for the different crops, because of differences in growth rate. Therefore, the data are analyzed separately for each crop. However, for convenience, samples are designated as stage 1, 2, and 3 samples in all cases.

Samples for AR assays were collected between 0900 and 1200 hrs. Roots were excavated carefully so that most nodules remained attached. Stems

were cut off at the cotyledonary node. Detached nodules were recovered and included in the sample. Roots and nodules were washed in tap water, enclosed in 500 ml flasks, and incubated in a 9:1 air:acetylene atmosphere at 30°C. Samples were removed at 30 minute intervals for determination by gas chromatography, using a standard method (Dart et al., 1972). From each of the crops two or more plants per replication were collected at each date for assay. A theoretical $N_2:C_2H_2$ ratio of 1:3 was used in converting the acetylene reduction activity to N fixation. The actual measurements like root weights, shoot weights and nodule weights and the derived measurements like specific nodule activity (SNA) are based on dry weights. The per ha N fixation yields were estimated by multiplying the per plant AR activity with the per ha plant populations given in Table 3-1. To reduce the high variability of the data logarithmic transformation procedure was used (LeClerg et al., 1962). The interpretations are based on the transformed data and the original data are presented in the text.

## Results and Discussion

Nodules first appeared on the plants 10-16 days after planting (Table 3-1). Nodules varied greatly in shape and size. The velvetbean had largest nodules, which appeared in large clumps. The relationships of nodule dry weights (NDW) and AR rates are generally positive and are presented with significant levels in Table 3-2. Similarly, Westermann and Kolar (1978) observed positive relationships. The plant dry weights (PDW) and AR rates are positively related in case of jointvetch and alyceclover (Table 3-2).

Table 3-1. Incubation time, plant populations, first nodule, flower and pod appearance times, and micro-Kjeldahl N yield in top growth of summer legumes.

| Legume | Incubation time | Plant population 1980 | Plant population 1981 | First nodule after planting | Nitrogen yield† | Floral initiation | Pod initiation |
|---|---|---|---|---|---|---|---|
| | — min — | — plants $m^{-2}$ — | | — days after planting — | kg $ha^{-1}$ | — days after planting — | |
| 305070 mungbean | 80 | 33 | -- | 10 | 30 | 40 | 50 |
| FL 81d pigeonpea | 60 | 12 | -- | 10 | 200 | 55 | 100 |
| Norman pigeonpea | 60 | 12 | -- | 10 | 220 | 90 | 120 |
| Showy Crotalaria | 60 | 47 | 50 | 10 | 140 | 135 | 150 |
| Slenderleaf crotalaria | 60 | 18 | -- | 13 | 180 | 130 | 150 |
| Jointvetch | 230 | 53 | 55 | 10 | 160 | 150 | 165 |
| Hairy indigo | 90 | 44 | 42 | 16 | 180 | 130 | 160 |
| Velvetbean | 117 | 9 | -- | 14 | 200 | 100 | 120 |
| Jupiter soybean | 80 | 18 | -- | 15 | 130 | 110 | 130 |
| Alyceclover | 60 | 74 | -- | 10 | 70 | 90 | 110 |

†Micro-Kjeldahl estimation; average of the same seasons when acetylene reduction estimations were made.

Table 3-2. Correlation coefficients of nodule dry weight (NDW) and plant dry weights (PDW) with N fixed $ha^{-1}$ $day^{-1}$.

| Legume | N fixed $ha^{-1}$ $day^{-1}$ With NDW | With PDW |
|---|---|---|
| Mungbean | 0.76† 0.0004 | -0.11 0.64 |
| FL 81d pigeonpea | 0.71 0.003 | 0.44 0.035 |
| Norman pigeonpea | 0.49 0.013 | -0.37 0.07 |
| Showy crotalaria | 0.27 0.185 | -0.47 0.019 |
| Slenderleaf crotalaria | 0.35 0.087 | -0.14 0.505 |
| Hairy indigo | 0.76 0.0001 | 0.23 0.269 |
| Velvetbean | 0.20 0.327 | -0.17 0.411 |
| Jointvetch | -- | 0.72 0.0001 |
| Soybean | 0.23 0.219 | -0.106 0.586 |
| Alyceclover | 0.959 0.0001 | 0.87 0.0010 |

†Top correlation coefficients under probability level.

Crop Response

PI 305070 mungbean

Acetylene reduction activity was estimated on days 33, 83, and 108 of the growing season (Table 3-3). There were no statistically significant differences between treatments (Table 3-3).

Nitrogenase activity was highest (0.43 kg N $ha^{-1}$ $day^{-1}$) on day 33. On day 108 this had dropped to a very low rate (0.041 kg N $ha^{-1}$ $day^{-1}$) (Fig. 3-1). This could be due to the significantly higher nodule production on day 33 than days 83 and 108 (Table 3-3). Flowers on this crop were first observed on the 40th day and pod initiation was seen on the 50th day. Therefore, it appears that the AR activity was highest at flowering stage and decreased afterward. Talekar and Kuo (1979) compared 20 mungbean varieties and found AR activity much greater at 5 weeks after planting than at later dates. These studies imply that the period of greatest nitrogenase activity in mungbean is the first 6-7 weeks after planting or until about pod initiation stage.

FL 81d pigeonpea

On day 98, AR rates of nonfumigated plots were significantly higher than the fumigated plots. Differences were not significant on day 61 sampling (Table 3-3). Acetylene reduction activity was approximately constant over the growing season (Table 3-3) which includes vegetative and reproductive stages. Similar results were reported by Dalal and Quilt (1977). Rao et al. (1981) found with pigeonpea cv 'ICP-1' on day 80 an AR rate of 5.3 nm $plant^{-1}$ $hr^{-1}$. They found nodule weights of 203 mg $plant^{-1}$, about 40% less than that obtained in this experiment.

Table 3-3. Nitrogenase activity measurements of tropical legumes under fumigated (F) and nonfumigated (NF) conditions, 1980 and 1981.

| Legume and season | Days after planting | $C_2H_4$ produced F† | $C_2H_4$ produced NF‡ | $C_2H_4$ produced Mean | Nodule weight F | Nodule weight NF | Nodule weight Mean | Specifica nodule activity (SNA) F | Specifica nodule activity (SNA) NF | Specifica nodule activity (SNA) Mean | Root weight F | Root weight NF | Root weight Mean | Shoot weight F | Shoot weight NF | Shoot weight Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $\mu m\ hr^{-1}\ plant^{-1}$ | | | mg $plant^{-1}$ | | | $\mu m\ g^{-1}\ hr^{-1}$ | | | g $plant^{-1}$ | | | g $plant^{-1}$ | | |
| PI 305070 | 33 | -- | 5.7 | 5.7 | -- | 170 | 170 a§ | -- | 34.0 | 34.0 | -- | 0.3 | 0.3 b | -- | 2.4 | 2.4 |
| mungbean, | 83 | 1.4 | 4.8 | 3.1 | 31 | 11 | 21 b | 45.0 | 436.0 | 241.0 | 6.3 | 5.6 | 6.0 a | 43* | 18.0 | 31.0 |
| 81 | 108 | -- | 0.6 | 0.6 | -- | 2 | 2 b | -- | 300.0 | 300.0 | -- | 3.1 | 3.1 ab | -- | 18.0 | 18.0 |
| FL 81d | 32 | -- | 10.6 | 10.6 | -- | 180 | 180 | -- | 59.0 | 59.0 | -- | 0.3 | 0.3 b | -- | 2.1 | 2.1 b |
| pigeonpea, | 61 | 10.7 | 9.0 | 9.9 | 380 | 320 | 350 | 28.0 | 28.0 | 28.0 | 5.2 | 2.5 | 3.9 b | 87 | 57.0 | 72.0 ab |
| 81 | 98 | 6.9* | 13.9 | 10.4 | -- | -- | -- | -- | -- | -- | 16.3 | 17.2 | 16.8 a | 115 | 145.0 | 130.0 a |
| Norman | 43 | -- | 11.7 | 11.7 a | -- | 290 | 290 | -- | 40.0 | 40.0 a | -- | 0.9 | 0.9 b | -- | 8.5 | 8.5 b |
| pigeonpca, | 82 | 14.0 | 10.5 | 12.3 a | 1630 | 1170 | 1400 a | 9.0 | 9.0 | 9.0 b | 14.3 | 9.7 | 12.0 b | 96 | 66.0 | 81.0 b |
| 81 | 115 | 4.3 | 2.7 | 3.5 b | 670 | 740 | 705 b | 6.0 | 4.0 | 5.0 b | 28.2 | 31.6 | 29.9 a | 196 | 210.0 | 203.0 a |
| Showy | 92 | -- | 2.4 | 2.4 | -- | 150 | 150 | -- | 16.0 | 16.0 | -- | 2.5 | 2.5 | -- | 25.0 | 25.0 |
| crotalaria, 80 | 115 | -- | 1.1 | 1.1 | -- | 115 | 115 | -- | 10.0 | 10.0 | -- | 10.5 | 10.5 | -- | 55.0 | 55.0 |
| Showy | 32 | -- | 5.3 | 5.3 | -- | 130 | 130 | -- | 41.0 | 41.0 a | -- | 0.2 | 0.2 b | -- | 1.5 | 1.5 b |
| crotalaria, | 82 | 1.3 | 1.3 | 1.3 | 160 | 260 | 210 | 8.0 | 5.0 | 6.5 b | 3.2 | 4.9 | 4.1 b | 27 | 38.0 | 33.0 a |
| 81 | 108 | 1.0 | 1.7 | 1.4 | 110 | 120 | 115 | 9.0 | 14.0 | 11.5 b | 10.2 | 11.4 | 10.8 a | 52 | 64.0 | 58.0 a |
| Slenderleaf | 43 | -- | 7.1 | 7.1 b | -- | 350 | 350 | -- | 20.0 | 20.0 b | -- | 0.7 | 0.7 b | -- | 3.4 | 3.4 b |
| crotalaria, | 63 | 26.7* | 17.0 | 21.9 a | 600 | 520 | 560 | 45.0 | 33.0 | 39.0 a | 2.7 | 2.0 | 2.4 b | 21 | 17.0 | 19.0 b |
| 81 | 124 | 10.9 | 10.0 | 10.5 b | 980 | 640 | 810 | 11.0 | 16.0 | 13.5 b | 21.9 | 20.9 | 21.4 a | 215 | 186.0 | 201.0 a |
| Hairy | 95 | -- | 0.8 | 0.8 | -- | 250 | 250 | -- | 3.2 | 3.2 | -- | 3.0 | 3.0 | -- | 50.0 | 50.0 |
| indigo, | 137 | -- | 1.3 | 1.3 | -- | 200 | 200 | -- | 6.5 | 6.5 | -- | 3.2 | 3.2 | -- | 48.0 | 48.0 |
| 80 | 158 | -- | 3.8 | 3.8 | -- | 210 | 210 | -- | 18.0 | 18.0 | -- | 4.0 | 4.0 | -- | 52.0 | 52.0 |

Table 3-3.--Continued.

| Legume and season | Days after planting | $C_2H_4$ produced F† | NF‡ | Mean | Nodule weight F | NF | Mean | Specifica nodule activity (SNA) F | NF | Mean | Root weight F | NF | Mean | Shoot weight F | NF | Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | µm hr$^{-1}$ plant$^{-1}$ | | | mg plant$^{-1}$ | | | µm g$^{-1}$ hr$^{-1}$ | | | g plant$^{-1}$ | | | g plant$^{-1}$ | | |
| Hairy indigo, 81 | 33 | -- | 0.6 | 0.6 | -- | 97 | 97 | -- | 6.0 | 6.0 b§ | -- | 1.5 | 1.5 b | -- | 15.0 | 15.0 |
| | 66 | 1.7 | 1.6 | 1.7 | 320 | 280 | 300 | 5.3 | 5.7 | 5.5 b | 2.9 | 3.1 | 3.0 ab | 40 | 55.0 | 48.0 |
| | 155 | 3.6 | 2.4 | 3.0 | 285 | 140 | 213 | 13.7 | 17.1 | 14.7 a | 3.9 | 5.6 | 4.8 a | 54 | 59.0 | 57.0 |
| Velvetbean, 81 | 32 | -- | 18.4 | 18.4 a | -- | 250 | 205 b | -- | 73.6 | 73.6 a | -- | 0.5 | 0.5 c | -- | 4.0 | 4.0 b |
| | 63 | 12.1 | 6.1 | 9.1 a | 1980 | 1150 | 1565 a | 6.1 | 5.3 | 5.7 b | 2.8 | 2.8 | 2.8 b | 91 | 87.0 | 89.0 a |
| | 124 | 8.5 | 4.8 | 6.7 b | 140 | 90 | 115 b | 60.7 | 53.3 | 58.3 b | 4.1 | 3.6 | 3.9 a | 51 | 54.0 | 53.0 a |
| Jointvetch, 80 | 59 | -- | 2.6 | 2.6 b | -- | -- | -- | -- | -- | -- | -- | 2.0 | 2.0 b | -- | 10.0 | 10.0 b |
| | 130 | -- | 11.8 | 11.8 a | -- | -- | -- | -- | -- | -- | -- | 7.6 | 7.6 a | -- | 55.0 | 55.0 a |
| | 148 | -- | 9.3 | 9.3 a | -- | -- | -- | -- | -- | -- | -- | 10.0 | 10.0 a | -- | 80.0 | 80.0 a |
| Jointvetch, 81 | 32 | -- | 1.5 | 1.5 b | -- | -- | -- | -- | -- | -- | -- | 0.2 | 0.2 b | -- | 0.5 | 0.5 b |
| | 82 | 15.1 | 12.3 | 13.7 a | -- | -- | -- | -- | -- | -- | 4.0 | 4.0 | 4.0 b | 21 | 16.0 | 18.5 b |
| | 151 | 11.8 | 16.5 | 14.2 a | -- | -- | -- | -- | -- | -- | 6.6 | 13.6 | 10.1 a | 64 | 108.0 | 86.0 a |
| Soybean, 81 | 61 | 5.8 | 5.7 | 5.8 b | 180 | 100 | 140 b | 32.3 | 57.0 | 44.6 a | 1.6 | 1.1 | 1.4 c | 9 | 2.6 | 5.8 b |
| | 98 | 21.6* | 10.1 | 15.9 | 270 | 210 | 240 b | 80.0 | 48.1 | 66.2 a | 4.9 | 5.8 | 5.4 b | 43 | 43.0 | 43.0 b |
| | 153 | 10.9 | 8.2 | 9.6 ab | 1370 | 780 | 1075 | 8.0 | 10.5 | 9.5 b | 15.3 | 14.1 | 14.7 a | 117 | 120.0 | 119.0 a |
| Alyceclover, 81 | 43 | -- | 0.6 | 0.6 b | -- | 23 | 23 | -- | 26.1 | 26.1 | -- | 0.2 | 0.2 b | -- | 0.6 | 0.6 |
| | 106 | -- | 6.9 | 6.9 a | -- | 68 | 68 | -- | 101.5 | 101.5 | -- | 5.1 | 5.1 a | -- | 30.0 | 30.0 |

†F = Fumigated.
‡NF = Nonfumigated.
*Means in the same row marked with an asterisk are significantly different at 5% level according to Duncan's Multiple Range Test.
§Within each crop, means in the same column not marked with the same letter are significantly different at 5% level according to Duncan's Multiple Range Test.

Norman pigeonpea

Unlike line FL 81d, Norman showed very little difference between fumigated and nonfumigated treatments (Table 3-3). The AR activity was high, up to 82 (0.33 kg N $ha^{-1}$ $day^{-1}$) and then dropped significantly (0.1 kg N $ha^{-1}$ $day^{-1}$) by day 115 (Table 3-3).

This reduction in activity was a direct effect of a drop in the SNA from day 43 to day 82 to day 115 (Table 3-3) and drop in nodule weight from day 82.

The other possible reason for low AR activity during reproductive stage (Table 3-1) could be the root systems of the pigeonpea which was large and diffuse, and it was impossible to recover all the nodules from the soil. After the first sample, most of the nodules were found on the secondary roots, attached very loosely, and these roots grew as deep as 2 m. Therefore, it is certain that many nodules were not found and that data reported here underestimate actual AR. These values should give us information about the general pattern of AR and SNA over time.

Showy crotalaria

In the year 1980, the AR activity was measured from nonfumigated plots on days 92 and 115 (Table 3-3); there were no signficant differences between sampling times in the year 1981. It was measured on days 32, 82, and 108 from both fumigated and nonfumigated plots (Table 3-3). There were no statistically significant differences between fumigated and nonfumigated plots and among sampling periods. The nitrogenase activity decline trend over time was probably due to the significant drop in SNA (Table 3-3). The first seven weeks apparently are most important for the nitrogenase activity in this crop.

Slenderleaf crotalaria

Acetylene reduction rates were significantly higher in the fumigated plots on day 63 than in the nonfumigated plots. The SNA and nodule dry weight (NDW) of the fumigated treatment were higher than nonfumigated plots and that probably contributed to the differences in their activity. The day 124 sample did not show significant differences between fumigated and nonfumigated treatments. Day 63 AR activity was significantly higher than day 43 and day 124; however, the AR activity was higher throughout the season compared to other crops.

Hairy indigo

Acetylene reduction measurements were taken in 1980 and 1981 at three growth stages (Table 3-3). In 1980 AR activity was measured only in nonfumigated plots; the results did not differ significantly over the sampling periods. Statistical comparison of fumigated and nonfumigated plots (1981) for nitrogenase activity showed no significant differences. Acetylene reduction and SNA were significantly higher in reproductive stage (Table 3-1) than in vegetative stage. Similarly, Ratner et al. (1979) reported that in peanuts the $N_2$ fixation was very low until 50-60 days after planting and the maximum activity was noticed during pod filling stage. Ezedinma et al. (1979) reported that hairy indigo had 1300 mg fresh nodule weight plant$^{-1}$ in their experiment and this is close to the estimates in this experiment.

Velvetbean

The statistical comparison of fumigated and nonfumigated treatments for AR showed no significant differences on all the sample dates (Table 3-3). However, the fumigated plots consistently showed higher activity

(100% more on day 63 and 78% more on day 124) compared to the non-fumigated plots. Higher nitrogenase activity in the fumigated plots was associated with higher NDW. The AR was significantly higher on day 32, then dropped substantially by day 63 and continued to do so until day 124 (Table 3-3). The drop in the plant weights on day 124 sampling was due to the withering of the crop by that time. These data indicate that the active N fixation in this crop ranges between the third and eighth weeks after planting (vegetative stage). The lower nitrogenase activity during the reproductive stages (on days 63 and 124) could be partially attributed to the incomplete recovery of nodules from the secondary roots which spread near the soil surface to a distance of 2 to 3 m.

Jointvetch

In general, AR levels of 1980 and 1981 are similar (Table 3-3). However, the 1980 AR levels were lower than 1981. This could be due to the differences in the irrigation management between the two years; irrigation was more frequent in 1981. Quesenberry et al. (1982) reported that jointvetch maintained AR under flooding but not under moisture stress in a glasshouse experiment. In both the years, the AR rate started at a low level and then rapidly increased to significantly higher levels by the crop maturity stage (Table 3-1). The AR rate observed in this crop was the highest out of the nine legumes studied.

The increase in activity with age indicated that new nodules were constantly added as the crop grew and that the older nodules retained their effectiveness. Quesenberry et al. (1982) reported a high linear

correlation (R = 0.93) between AR and leaf biomass. Similar results in alfalfa were observed by Fishbeck and Phillips (1980).

Data from 1981 showed no significant differences between fumigated and nonfumigated plots for AR (Table 3-3). Since the activity was very high even on day 151 after planting, the whole plant growth needs to be considered important for nitrogenase activity.

Jupiter soybean

On day 98, the fumigated soybeans reduced significantly higher quantities of acetylene compared to the nonfumigated plants. There were no significant treatment differences on the other sample dates (Table 3-3). This was possible through higher SNA associated with the fumigated plots compared to the nonfumigated plots.

The AR increased significantly from day 61 to day 98, and then dropped slightly by day 153, the pod filling stage (Table 3-1). Westermann and Kolar (1978) reported that the activity in soybean rapidly increased from the third node vegetative (V3) to early pod filling (R3-R4) growth stages, thereafter decreasing to zero at physiological maturity (R9). However, Grubinger et al. (1982) reported that the soybean nodules located in deeper layers are more important for N fixation in the later part of the growth cycle and that has been commonly ignored due to the difficulties in recovering them.

Alyceclover

The regular alyceclover planting (Apr. 15th) along with the other crops studied was heavily infected with root knot nematodes, and no nodules could be obtained and therefore the activity was measured from a later June 4 planting of nonfumigated alyceclover. The nitrogenase

activity was very low on day 43, and then rose to significantly higher levels (from 0.09 to 1.15 kg N $ha^{-1}$ $day^{-1}$) by day 106 (Table 3-3). This higher activity at pod filling stage (Table 3-1) was also associated with the higher NDW and SNA compared to the initial sample. Since the activity increases over the crop growth period, the entire crop period needs to be considered as important for the nitrogenase activity.

## Fumigation Effects

The effect of fumigation on nitrogenase activity of crops was not consistent either with the individual crop or across the crops. The high variability can be attributed to the regular sampling error associated with the AR measurements. The high variability of the data between the replications of the same treatment (in spite of logarithmic transformation) caused the nonsignificance of the treatment effects. The enormous variability among the replications of the same treatment is a common problem with the AR procedure (Wacek and Brill, 1976).

The situations where the differences between the fumigated and nonfumigated treatments of a crop are larger are presented in Table 3-4. These relative AR activity numbers computed from Table 3-3 indicated substantial treatment differences for most of the crops at one sample time or other.

The possible effects of fumigation on AR rates could occur through the effect of the treatment on nematode populations. Nematode populations were periodically determined. On day 70, populations of root knot nematodes [<u>Meloidogyne incognita</u> (Kofoid and White) Chitwood] were significantly higher in mungbean roots from the nonfumigated

Table 3-4. Effect of fumigation on the nitrogenase activity of summer legumes.

| Legume | Days after planting | Relative AR activity NF‡ | Relative AR activity F† |
|---|---|---|---|
| | | % | % |
| PI 305070 mungbean | 83 | 357 | 100 |
| FL 81d pigeonpea | 98 | 200 | 100 |
| Showy crotalaria | 108 | 200 | 100 |
| Norman pigeonpea | 115 | 100 | 162 |
| Slenderleaf crotalaria | 63 | 100 | 156 |
| Velvetbean | 63 | 100 | 100 |
| | 124 | 100 | 178 |
| Jupiter soybean | 98 | 100 | 214 |
| | 153 | 100 | 153 |

†F = Fumigated.
‡NF = Nonfumigated.

(92/10 g) plots compared to the fumigated plots (49/10 g). Root knot and other nematode populations did not vary signficantly between fumigated and nonfumigated treatments of other legumes. On day 130, there were no differences for the root-knot nematode populations in all the legumes between the fumigated and nonfumigated treatments plots. The nonfumigated mungbean (54/10 g), FL 81d (22/10 g) and Norman (54/10 g) pigeonpea, showy crotalaria (498/10 g), Jupiter soybean (135/10 g) and slenderleaf crotalaria (182/10 g) had significantly higher lesion nematodes [Pratylenchus beachyurus (Godfrey) Goodey] in roots compared to their fumigated counterparts (20, 0, 14, 18, 0 and 40 per 10 g roots, respectively). There were no differences in the soil populations of lesion nematodes between fumigated and nonfumigated treatments. Also, no treatment differences were found for the other nematodes like sting (Belonolaimus longicaudatus Rau.), ring (Criconemoides spp.) etc., in all the legumes studied. Complete information on nematode population dynamics is available in Chapter Two.

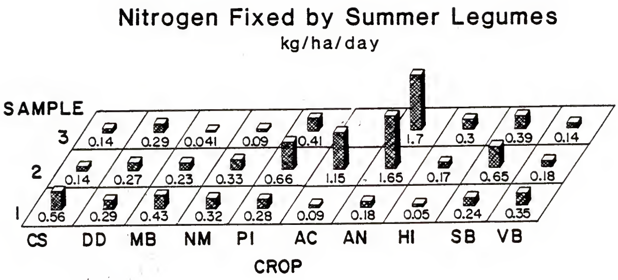
An examination of the nematode data and AR data was inconclusive and no single cause-and-effect relationship could be identified. Baldwin et al. (1979) reported that root knot nematodes stimulated N fixation in soybean cvs 'Lee 68' (2 of 4 test dates) and 'Forrest' (1 of 4 test dates). On other sampling dates, however, N fixation was either depressed or unaffected by nematodes. They concluded that the population of the Meloidogyne incognita stimulated N fixation at specific intervals and and depressed at other times. Hedrick and Southards (1976) reported similar results. In the present experiment there were no significant differences in the root knot populations of soybean between fumigated

and nonfumigated treatments. However, there were more lesion nematodes in the nonfumigated soybean roots (135/10 g) on day 130 compared to the fumigated treatment (0/10 g). Also, AR rates were consistently higher in the fumigated plots. This suggests that the lesion nematode adversely affects N fixation in this crop. However, in the mungbean roots higher populations of root knot nematodes gave higher nitrogen fixation.

Some authors reported that controlling nematodes resulted in better nodulation and crop growth (Truelove et al., 1977; Lewis et al., 1977; Srivastava et al., 1979). Hussey and Barker (1974) reported that lesion nematode (P. penetrans) had little effect on nodulation in soybean, peanut (Arachis hypogaea L.) and cowpea [Vigna unguiculata L. Walp] but damages nodules of garden pea (Pisum sativum L.). These results suggest that the effect of the nematodes on N fixation is inconsistent.

## Specific Nodule Activity

The fumigation and nonfumigation effects on N fixation are inconsistent with the time and the crop and the differences are generally nonsignificant. Average values of 1981 fumigated and nonfumigated treatments for amount of N fixation based on AR (Fig. 3-1) indicate that jointvetch was superior to the other crops as a nitrogen source; followed by slenderleaf crotalaria, alyceclover and soybean. The crops, hairy indigo, showy crotalaria, and velvetbean had lower AR activity during the reproductive stages (Table 3-3) which is very unusual with the other crops.




Note[1]: Crop acronyms - cs = showy crotalaria, DD = FL 81d pigeonpea, MB = PI 305070 mungbean, NM = Norman pigeonpea, PI = slenderleaf crotalaria, AC = alyceclover, HI = hairy indigo, SB = Jupiter soybean, VB = velvetbean, AN = jointvetch.

Note[2]: Samples 1, 2, and 3 were different dates for each crop as shown in Table 3-3.

Fig. 3-1. Nitrogenase activity of tropical legumes (averages of 1981 fumigated and nonfumigated treatments) during their growth period.

The SNA (Table 3-3) demonstrated that mungbean and alyceclover had very high per gram nodule activity compared to the other crops. Since all the legumes in the study except soybean were nodulated with cowpea-type Rhizobium sp., it could be concluded that the per gram nodule activity is more a response of plant species than the inoculant itself.

## Micro-Kjeldahl Estimation vs Acetylene Reduction

A comparison of AR data of the legumes with micro-Kjeldahl N yield (Table 3-1) indicated very wide variations. This is especially the case for hairy indigo, velvetbean and showy crotalaria which also had lower AR during reproductive stages. Similar results were reported by Hardy and Havelka (1975) with soybeans. Since AR values are usually extrapolated to 24 hours of the day and for the season, frequent samples must be taken. Since micro-Kjeldahl estimations include an accumulation for the season it is often beleived to be a better quantitative method.

Data from the present study indicated substantial variations among the legumes studied in seasonal production of nitrogen. Jointvetch, alyceclover and slenderleaf crotalaria had the highest AR rates.

## SUMMARY AND CONCLUSIONS

Effects of several tropical legumes and a marigold variety on the yield and parasitic nematode population levels of succeeding crops were studied in field experiments in 1979, 1980, and 1981. The legumes were grown in three different parts of the summer season: early (Apr. 15th-Aug. 15th), full (Apr. 15th-Sept. 15th), and late (June 7th-Sept. 15th). All plant material was incorporated into its original plot at the end of the summer season.

Nitrogen fixation rates were estimated periodically in all these legumes by acetylene reduction (AR) procedure. Highest N-fixation rates were found with jointvetch (1.7 kg N $ha^{-1}$ $day^{-1}$), and alyceclover (1.15 kg N $ha^{-1}$ $day^{-1}$). Jupiter soybean and slenderleaf crotalaria had an intermediate level of fixation, 0.65 kg N $ha^{-1}$ $day^{-1}$. Soil fumigation influenced N fixation but the effect was not consistent either with the time of sampling or with the crop.

The dry matter yields of these crops were influenced by their growing periods. All the legumes yielded significantly higher or equal dry matter in the full summer growth with the exception of alyceclover which was severely affected by root knot nematodes in the April plantings. The dry matter yields of these crops from their preferred growth periods in t $ha^{-1}$ were 2.8 for mungbean, 9.1 for FL 45a pigeonpea, 10.8 for FL 81d pigeonpea, 13.3 for Norman pigeonpea, 10.2 for showy crotalaria, 14.4 for slenderleaf crotalaria, 13 for hairy indigo, 10 for jointvetch, 7.1 for velvetbean, 0.5 for sesbania, 1.9 for lablab, 9.8 for soybeans, 5.6 for alyceclover and 5.1 for marigold.

Cumulative N yields in these legumes by the end of the growing season were estimated by micro-Kjeldahl procedure. Most of the legumes yielded higher N by growing full summer season with few exceptions such as velvetbean which yielded higher N in early summer and Jupiter soybean and alyceclover which yielded higher N in late summer. Nitrogen yields (from the preferred part of the summer season) in kg $ha^{-1}$ were 190 for velvetbean, 260 for FL 45a pigeonpea, 250 for Norman pigeonpea, 270 for slenderleaf crotalaria, 220 for hairy indigo, 210 for Jupiter soybean, 70 for alyceclover, 15 for sesbania, 40 for lablab and mungbean, 190 for FL 81d pigeonpea, 170 for jointvetch and 60 for marigold.

The following seasons' grass crops--rye, ryegrass, corn, and wheat--responded positively to the green manuring of tropical legumes with 15, 13, 16, and 18% higher N yields, respectively, than wheat N yield from summer fallowed plots. The percent recovery of green-manured N by the grass crops was low (approximately 12%) because of the low N concentration (1.5 to 2.5%) of the green-manured legumes. However, the unavailable part of green-manured N to the immediately succeeding crops should be available to the other crops on a long-term basis.

Parasitic nematode populations were monitored in the green manure crops and in the succeeding seasons' grasses (rye, corn, ryegrass, and wheat) and legumes (snap beans and soybeans). The results indicate that crops planted following incorporation of Norman pigeonpea, FL 81d pigeonpea, showy crotalaria, slenderleaf crotalaria, hairy indigo, jointvetch, velvetbean, and Crackerjack marigold had fewer or negligible numbers of root knot nematodes. Similarly, crops planted after

jointvetch, hairy indigo, showy crotalaria, and slenderleaf crotalaria had fewer or negligible numbers of sting nematodes and after hairy indigo and marigold had fewer or negligible numbers of lesion nematodes. Early summer EDB fumigation generally controlled only sting and ring nematodes. Mungbean, alyceclover, sesbania, and lablab planted on the fumigated plots were also infected heavily by root knot nematodes and that resulted in heavy infection of following crops. This indicates that rotation with nonhost crops is definitely advantageous over fumigation.

These studies suggest that manuring selected tropical legumes contributes biologically-fixed N and nematode control to the succeeding crops. This kind of rotation could lead to high succeeding crop yields with low N fertilizer and no fumigation. Further research should be initiated on the feasibility of such low input cropping systems.

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